ANNUAL CONVENTION, DETROIT, MICH., MAY 21-25, 1923

VOL. 10 NO. 1 JANUARY, 1923

PROCEEDINGS 43RD YEAR

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

PUBLISHED IN JANUARY, MARCH, MAY, JULY, SEPTEMBER AND NOVEMBER

BY THE

AMERICAN WATER WORKS ASSOCIATION

AT MOUNT ROYAL AND GUILFORD AVENUES, BALTIMORE, MD.

SECRETARY'S OFFICE, 153 WEST 71ST ST., NEW YORK

EDITOR'S OFFICE, 16 WEST SARATOGA STREET, BALTIMORE, MARYLAND

Subscription price, $7.00 per annum

Entered as second class matter April 10, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917; authorized August 6, 1918

Made in United States of America

Eng.
Direct

TABLE OF CONTENTS

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings
Discussion of all papers is invited

VOL. 10 JANUARY, 1923 No. 1

PURIFICATION OF WATER FOR INDUSTRIAL USE[1]

BY SHEPPARD T. POWELL[2]

There are few natural resources of greater importance to a country than its water. The industrial activities of the world are dependent largely upon fresh water supplies, as essential to industrial life as fuel or raw materials. In spite of the obvious importance of water in the commercial world, little has been published concerning the purification of water for industrial use. The Proceedings of this Association and of other scientific bodies devoting their activities to water purification and allied subjects are surprisingly barren on the question of water purification for industrial use, although much appears on water treatment for potable purposes.

The nature of the quality of water desirable for drinking and household use is fairly well standardized, so that the degree of purification for one community is much the same as for another. A satisfactory water, considered from a sanitary standpoint, is one that is practically free from suspended solids, contains no appreciable amount of color and has in it no substance, either mineral or organic, injurious to the health or comfort of the consumers. No such simple standard as this may be established for waters to be used in industrial

[1] Presented at the Philadelphia Convention, May 18, 1922.

[2] Chemist, Baltimore County Water and Electric Company, Baltimore, Md.

processes. A water supply may contain ingredients that are helpful or even essential to the manufacture of one product, while the same water may be highly objectionable for other manufacturing processes. It is not surprising, therefore, that so little has been published in reference to the purification of water supplies for the various industries, as no general method of treatment is applicable to all conditions. Treatment of water for commercial use requires frequently special investigation, the results of which are rarely published.

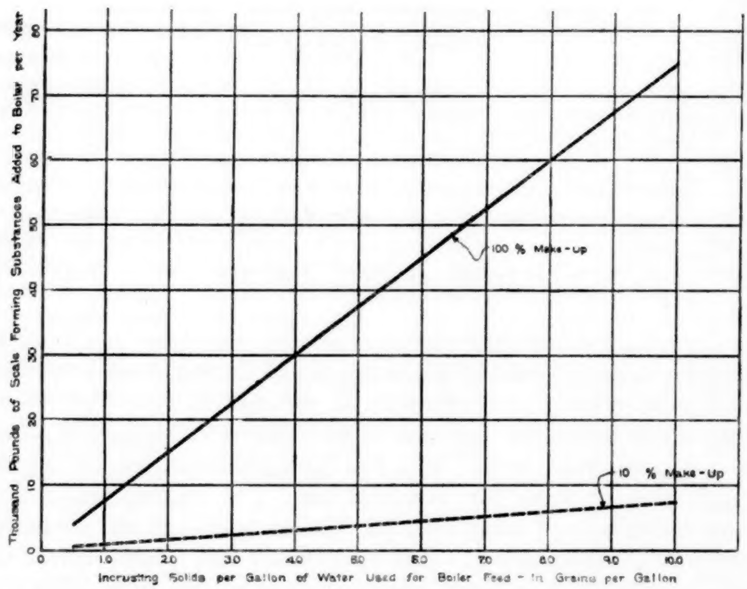

FIG. 1. SCALE FORMING SOLIDS DEPOSITED FROM WATERS OF DIFFERENT HARDNESSES USED FOR BOILER FEED

1300 h. p. boiler, 250 per cent rating 60 per cent of time in service during one year.

Water for industrial uses may be divided into two main classes: boiler feed water and water required in the various arts and trades. Of these two, the requirements for steam making are by far the greater and more important economically. A perfect water for steam boilers is one that will not deposit scale, mud, or sludge, will not corrode, and will cause neither priming nor foaming. Few waters

in their natural state fulfill these conditions. Waters of this kind are obtainable, therefore, only by carefully designed and operated purification systems. The high cost of fuel and the increased wages for labor have required higher boiler efficiencies, so that within the past few years more careful study has been given to boiler water treatment, in order to reduce losses from scale and corrosion. The amount of scale-forming matter that will deposit on the tubes and shells of a boiler will vary with the kind of water used. With hard waters these deposits may become very great, as is shown graphically in figure 1.

Water treatment practice differs materially for railroad and stationary boilers, owing to the radically different types of equipment and operating conditions. For this reason, each of these uses for steam making should be discussed separately. In railroad use treatment is limited generally to sedimentation, filtration and lime and soda softening. In some instances, neutralizing the acidity also assumes considerable importance. In stationary boiler practice, however, a comparatively large number of methods of water preparation are available, permitting considerable flexibility of operation.

TREATMENT OF WATER FOR STATIONARY BOILERS

In practically all stationary boiler plants some form of water treatment is employed. Operators of small boilers rely almost entirely upon boiler compounds to correct water troubles. In larger installations water purification systems are used generally. Many of these are elaborate and produce a high degree of purification. The value of such plants has been demonstrated clearly within the past few years through the investigations carried on at a number of large power plants. The use of zeolite softeners and evaporators for the removal of encrusting solids and the exhaustion of dissolved gases from water by degassing apparatus have marked a distinct advance in the art of water purification which is probably little known to many of our members.

The methods of treatment of boiler waters in stationary plants are numerous and range from systems designed merely to remove suspended solids to elaborate arrangements for clarification, soften-

ing and degassing. The methods employed generally may be summarized as follows:

1. Sedimentation	6. De-concentration
2. Filtration	7. Degassing
3. Lime-soda softening (cold process)	8. Evaporation
4. Lime-soda softening (hot process)	9. Boiler compounds
5. Zeolite softening	

SEDIMENTATION

Settling or sedimentation basins are employed widely for the removal of suspended solids from waters which are to be used for making steam. The widespread application of this method of treatment is due to low cost of construction and simplicity of operation. When properly operated, settling basins or tanks are efficient and their use is warranted under certain conditions. In localities where the waters from surface streams contain only a small amount of scale-forming solids, but carry an appreciable amount of settleable solids, sedimentation alone or aided by a coagulant will greatly improve the quality of water. It is customary in many small plants to use two tanks, or tanks with double compartments, and to operate them intermittently. In other places, large, well-baffled basins are in service, either for complete treatment or as an adjunct to filtration. Such a system is in use at the Westport Steam Station of the Consolidated Gas Electric Light and Power Company of Baltimore. The raw water supply of this plant is taken from the Patapsco River, a stream often excessively turbid, so that a complete filtration plant is essential properly to prepare the water for boiler use. The plant consists of a large primary settling basin, baffled to prevent short circuiting and operated intermittently on the fill and draw plan. The discharge from this basin is pumped to a coagulating tank and flows from there by gravity to the filters, the effluents from which discharge into a clear well. This system is particularly interesting in this discussion, as it shows the high degree of efficiency obtained by the primary basin. From figure 2 it will be seen that, by the use of this basin, the suspended solids in the water applied to the coagulating basin were held to 10 p.p.m., or less, for thirty-eight (38) weeks during the year, although during the same period the solids in the river water ranged from 10 to 8,000 p.p.m. During several weeks in the summer the efficiency of the basin was reduced, due to high rating of the plant, which did not permit sufficient time for

settling, during a period when the river water contained high suspended matter.

It is preferable always to use filters to prepare water for boiler feed use, if the water supply contains much suspended matter, but if a filter cannot be used a properly operated tank or settling basin will reduce greatly troubles caused by mud deposits.

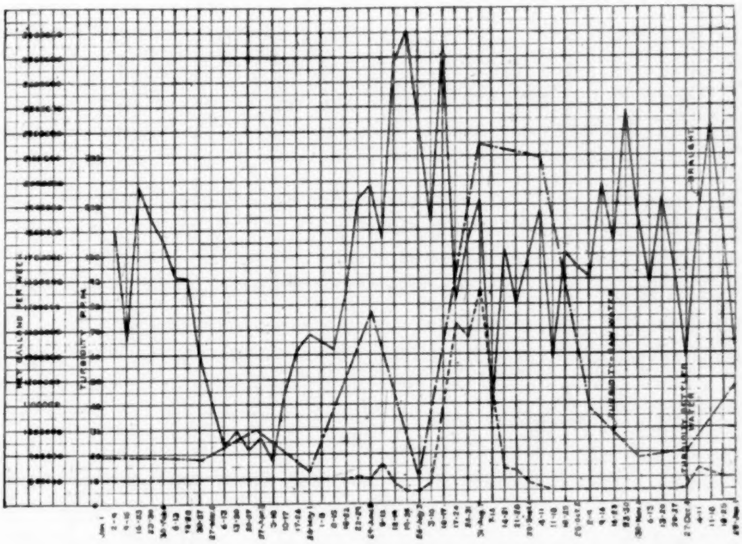

Fig. 2. Comparison of Turbidities in Effluent from Primary Settling Basin with Those of Raw Water, at Different Basin Draughts

Westport Steam Station, Consolidated Gas Electric Light and Power Company, Baltimore, Md.

FILTERS

Most filters in steam stations are of the pressure type, similar to those used for filtering water for domestic service, but operated generally at higher rates. Slow sand filters are seldom used, owing to the slow rates of filtration possible with such systems and to the area required for plants of this kind. Gravity filters of the rapid sand type have been installed in plants where the water consumption is high. The aforementioned installation at the Westport Station, Baltimore, Md., is an example of this kind of filtration system.

The pounds of solids removed per 1000 gallons of water at this plant are given in figure 3.

Filtered water is valuable for boiler feed, if the raw water supply is turbid or contains suspended solids from industrial pollution. Coagulation with alum or iron and lime is desirable, but, if the filters are used in conjunction with lime-soda softeners, no other coagulant generally is necessary. The removal of suspended solids

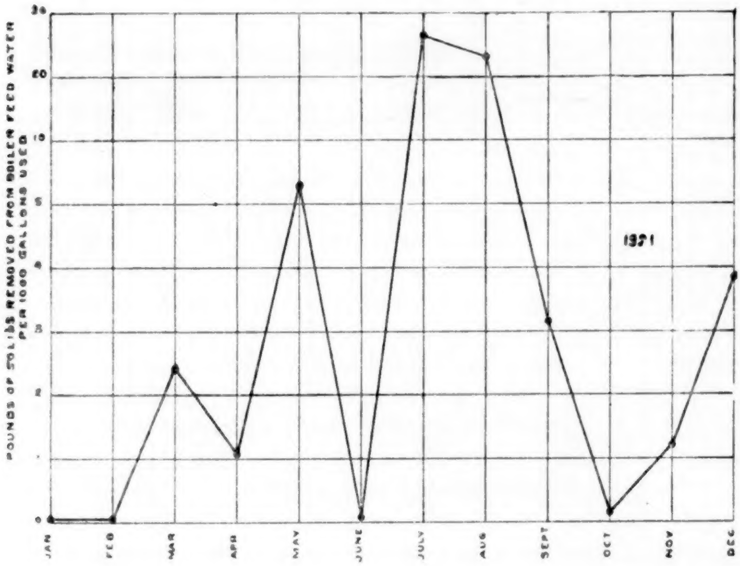

Fig. 3. Pounds of Solids Removed per 1000 Gallons of Boiler Feed Water

Westport Steam Station, Consolidated Gas Electric Light and Power Company, Baltimore, Md.

from feed water frequently brings about a material saving in boiler-plant operation. High turbidity in boiler feed water results often in burned tubes and bagged boilers, causing appreciable losses in heat and water through frequent blowing down of boilers. A graphic example of the saving resulting from filtration of water used in a large steam station[3] is given in figure 4. This curve represents the reduction in tube replacement after the installation of filters. The

[3] Consolidated Gas Electric Light & Power Co., Baltimore, Md.

total saving effected at this station, due to filtering the water supply, is not available, but it has been estimated at from $35,000 to $40,000 per year. This saving lies in fewer internal cleanings of boilers, better evaporation per pound of fuel burned, fewer blowdowns and in miscellaneous effects producing better overall boiler and plant efficiency.

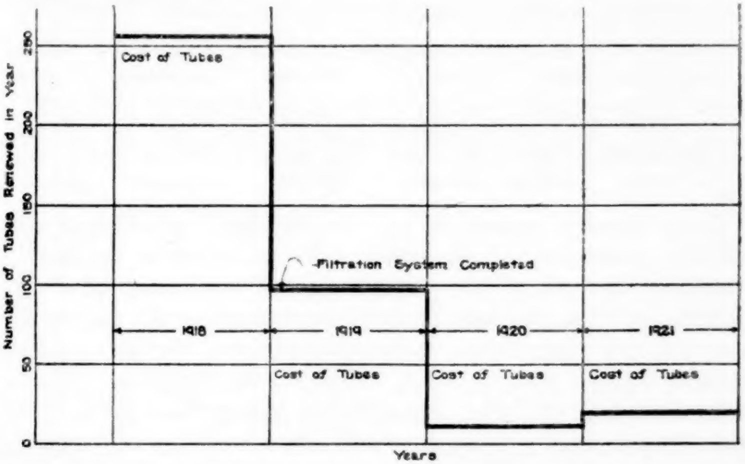

FIG. 4. REDUCTION IN TUBE RENEWALS AFTER BOILER FEED WATER TREATMENT BY FILTRATION

Westport Steam Station, the Consolidated Gas Electric Light and Power Company, Baltimore, Md.

LIME AND SODA SOFTENERS

Cold process

The principle involved in softening water by the lime and soda process is familiar probably to all interested in water purification, so that no detailed description of the method is required, other than to set forth the possible reactions that may take place when lime or soda is added to a hard water. These reactions follow:

$$Ca(HCO_3)_2 + Ca(OH)_2 = CaCO_3 + 2H_2O$$

Bicarbonate of lime + Lime water = Carbonate of lime + Water

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$

Sulfate of lime + Carbonate of soda (soda ash) = Carbonate of lime + Sulfate of soda

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl$$

Chloride of lime	+	Carbonate of soda	=	Carbonate of lime	+	Chloride of sodium

$$Mg(HCO_3)_2 + 2Ca(OH)_2 = Mg(OH)_2 + 2CaCO_3 + 2H_2O$$

Bicarbonate of magnesium	+	Lime water	=	Magnesium hydrate	+	Calcium carbonate	+	Water

$$MgSO_4 + Ca(OH)_2 + Na_2CO_3 = Mg(OH)_2 + CaCO_3 + NaSO_4$$

Sulfate of magnesium	+	Lime water	+	Carbonate of soda	=	Magnesium hydrate	+	Calcium carbonate	+	Sulfate of soda

$$MgCl_2 + Ca(OH)_2 + Na_2CO_3 = Mg(OH)_2 + CaCO_3 + NaCl$$

Magnesium chloride	+	Lime water and sodium carbonate	=	Magnesium hydrate	+	Calcium carbonate	+	Sodium chloride

Many types of apparatus are manufactured by different water softener companies, but all operate alike, in respect to the chemical reactions involved in the precipitation of hardening salts. The purification is accomplished merely by converting the soluble salts into insoluble compounds, which are removed by sedimentation alone or together with filtration. The process of softening water for boiler feed differs to some extent from softening water for municipal use. In municipal practice, lime and soda ash are the only chemicals used, and the process is carried on at or near the temperature of the air. In boiler feed water practice it is possible to accelerate the chemical reaction by heat, or to employ barium carbonate in place of soda ash, and in some softeners caustic soda alone is used in place of lime and soda.

Softening hard water for steam boilers by lime and soda in cold water is widely practiced and, when properly operated, gives efficient results. The lowest limit of hardness obtainable by this method is about 1.6 grains per gallon, expressed as calcium carbonate. In actual practice, however, the hardness of the treated water seldom, if ever, reaches the minimum figure. The hardness, even in well-operated plants, averages from 3 to 4 grains, and often higher, depending on the supervision given the system and the temperature conditions.

Practically all lime and soda softeners placed in operation within recent years are of the continuous type. The chemicals are added to the water continuously and the dose is varied in proportion to the rate of flow of water through the apparatus. Some intermittent softeners are in use at steam stations, but not many have been

installed in the larger and more modern stations. Intermittent softeners consist of two tanks, one tank used to soften and settle the water while soft water is drawn from the other tank, the water in which has been previously softened. The average period of detention in softening tanks for reaction and settlement is four hours. The detention period is the same for the intermittent or the continuous type of softener.

Hot process

The chemical reactions in softening water by means of lime and soda or with barium are greatly accelerated by heat. The velocity

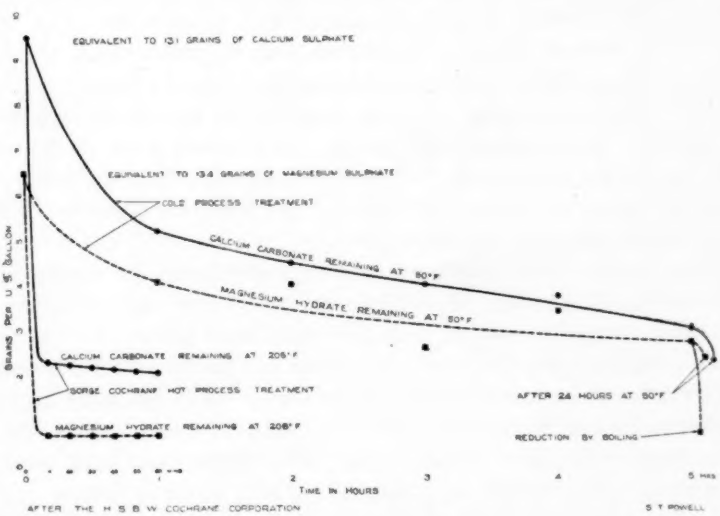

FIG. 5. REDUCTION OF LIME AND MAGNESIUM SALTS AT VARIOUS TEMPERATURES

of these reactions at different temperatures is shown by the curves on figure 5. To take advantage of these increased reaction velocities, hot lime and soda softeners have been designed and adopted widely for use in steam stations. The advantages of the hot over the cold process may be summarized briefly as follows:

1. Chemical reactions are more rapid and the precipitates settle more quickly.
2. There are less troubles from after precipitation.

3. There is less danger from priming or foaming, as there are less suspended solids carried into the boiler.

4. A hot softener also serves the purpose of a feed water heater, thereby saving fuel and space by combining a heater and a softener.

5. The process dispels dissolved gases and lessens corrosion from these constituents.

6. Hot lime and soda softeners are smaller than cold softeners, owing to reduced detention period required for reaction and sedimentation.

7. The softened water contains much less incrusting salts. Often the effluent from this type of softener contains less than 1 grain per gallon of scale forming constituents.

ZEOLITE SOFTENERS

Zeolite is the term applied to the hydrous silicate of alumina combined with calcium, sodium, potassium and other salts. The term zeolite is derived from the Greek, to boil, so named from the fact that zeolites exhibit a boiling phenomenon when intensely heated. When waters containing lime and magnesia are passed through these substances an exchange takes place. The zeolite gives up its soda content to the water and the lime and magnesia from the water are fixed in the zeolite, replacing the soda which has been released. When the soda content of the zeolite softener is exhausted, the softening action ceases. The substance is then regenerated by means of a concentrated solution of sodium chloride. The salt solution is allowed to stand in contact with the zeolite for a given period of time and is drained then from the bed, which is washed with fresh water. After this regeneration process the zeolite is ready again for service. Softening water by zeolites has been practiced fairly extensively in this country for over fifteen years. The process has been used in laundries and in other industries where soft water is desired. The adoption of zeolite softeners as a method of purification for boiler-feed use has attracted marked attention only within the past few years. In many respects softening boiler feed water by means of zeolite is ideal. The method is not applicable, however, to all conditions and should be adopted only after careful investigation of the quality of the raw water supply and of the operating conditions of the boilers and of the service to be rendered.

There are two kinds of zeolite softeners manufactured in this country. There are, however, several manufacturers of each kind. In one type of softener, synthetic zeolite is used and, in the other, natural zeolite is employed. The synthetic product is made either

by the chemical precipitation process or by fusion of the various constituents in the substances. The natural zeolite is mined and after passing through a refining and treating process is ready for use. The only differences in these zeolites are in the rate of exchange of sodium for hardening salts in the water, the activity of the material with respect to its regeneration properties and the specific gravity of the substances. All of the zeolites on the market today will soften water effectively and produce an effluent practically free from all incrusting solids.

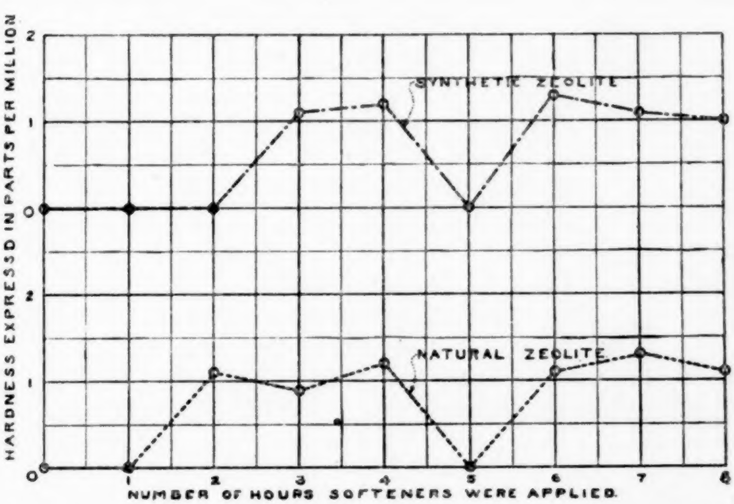

FIG. 6. HARDNESS IN WATER SOFTENED BY NATURAL AND SYNTHETIC ZEOLITIC MATERIALS

Manufacturers of this type of apparatus claim that the zeolite softeners will deliver water of zero hardness. Waters softened by zeolites will remove practically all the lime and magnesia contained in the untreated water supply, but at times there are traces of these salts present in the softened waters (see figure 6). The amount of these hardening salts present after passing zeolite softeners is so slight that no scale will form within the boilers when the softened water is used for boiler feed purposes. A number of plants have come under the observation of the writer and in no instance has mud, scale or sludge deposited within the boilers fed from zeolite softeners, provided the softeners have been operated efficiently. Practically

all plants using this type of softener have operated without surface condensers and the make-up water has been about 100 per cent. In only two plants that the writer has investigated has any difficulty been experienced from the use of zeolite softened water in the boilers. In both these cases the trouble experienced was due entirely to inefficient operation of the softeners. In each case the boiler room attendant failed to blow down the boiler so that the concentration of soda salts became so great that priming resulted.

Waters softened by zeolite material are well suited for use in boilers, as the necessity for the removal of scale from tubes and drums is eliminated, so that the boilers do not have to be cut out of service at frequent intervals for internal cleaning. The complete prevention of scale by this method of treatment permits better heat transfer and, therefore, a saving in fuel consumption.

Zeolite softeners are not so well adapted to treating extremely hard water, owing to the rapid concentration of soda salts in the boilers and to the relatively high cost of treatment. It is good practice in treating excessively hard water to use lime-soda softeners as a primary treatment and to pass the effluent from the chemical softener through a zeolite softener, to effect complete removal of the scale-forming solids. If such a combination is employed, the lime-soda treatment must be the cold process, as zeolite softeners do not operate successfully on hot water.

Where it is desired to eliminate scale-forming matter completely from water that is to be used in boilers, the type of purification to be employed is largely a question of the cost, as there are several combinations that will accomplish this purpose. At several places the combined lime-soda and zeolite systems have been installed and are operating satisfactorily. In general, it is not economical to treat a water by zeolite softeners as a complete system where the hardness of the water is in excess of 20 grains per gallon, but this depends largely upon local conditions, as waters containing 20 grains per gallon, or more, are being treated successfully by this method alone, without any other auxiliary treatment.

The advantages and disadvantages of softening water by zeolites, especially when the softened water is to be used for boiler water, may be summarized as follows:

ADVANTAGES OF ZEOLITE SOFTENERS

1. Practically complete removal of lime and magnesia salts from the water.
2. Less supervision than lime-soda softeners.
3. No chemicals are added to the water.

4. The softened water may be placed on the main supply line and will cause practically no loss of pressure.
5. No repumping of the softened water is required.
6. No mud, sludge or scale will deposit in the boilers.
7. The system will operate efficiently with fluctuating hardness of the untreated water.
8. This type of softener can be used to advantage to deliver water of practically zero hardness when operating on a very hard water, if the water is treated first by a lime and soda softener.

DISADVANTAGES OF ZEOLITE SOFTENERS

1. Zeolite softeners cannot operate efficiently on turbid waters or waters containing appreciable amount of iron and manganese, unless such waters are treated first to remove these constituents.
2. These softeners cannot be used to treat waters containing free acid, unless the acid is first neutralized.
3. Zeolite softeners cannot be operated economically with waters of high hardness.
4. Increase of sodium salts is proportionate to the lime and magnesia salts contained in the raw water supply.
5. There is a tendency of boiler water to prime or foam, unless the boilers are blown down sufficiently well to prevent high concentration of soda salts.
6. Increase in the amount of water required for blowdown of the boilers in order to control the concentration of soluble salts.
7. There is some loss of the zeolite, due to attrition.

The use of zeolite softeners in steam boiler practice is recommended particularly because of the fact that water so softened has less scale-forming constituents in it than can be accomplished by any other method of feed water treatment, with the exception of evaporation. The adoption of zeolite softeners will not solve all boiler feed water troubles and cannot be applied successfully for the purification of all kinds of hard waters. The method has its special sphere of usefulness and when so employed will effect a material saving in overall boiler plant efficiencies.

DECONCENTRATOR

The Hagan Deconcentrator is a type of water purification apparatus which has been designed recently to prevent accumulation of scale in boiler tubes and drums. This apparatus, shown in figure 7, is actually a small-pressure filter through which the boiler water is passed to remove the scale-forming ingredients after these salts have been thrown out of solution in the boiler by heat. The "de-

CUT OF HAGAN DECONCENTRATOR

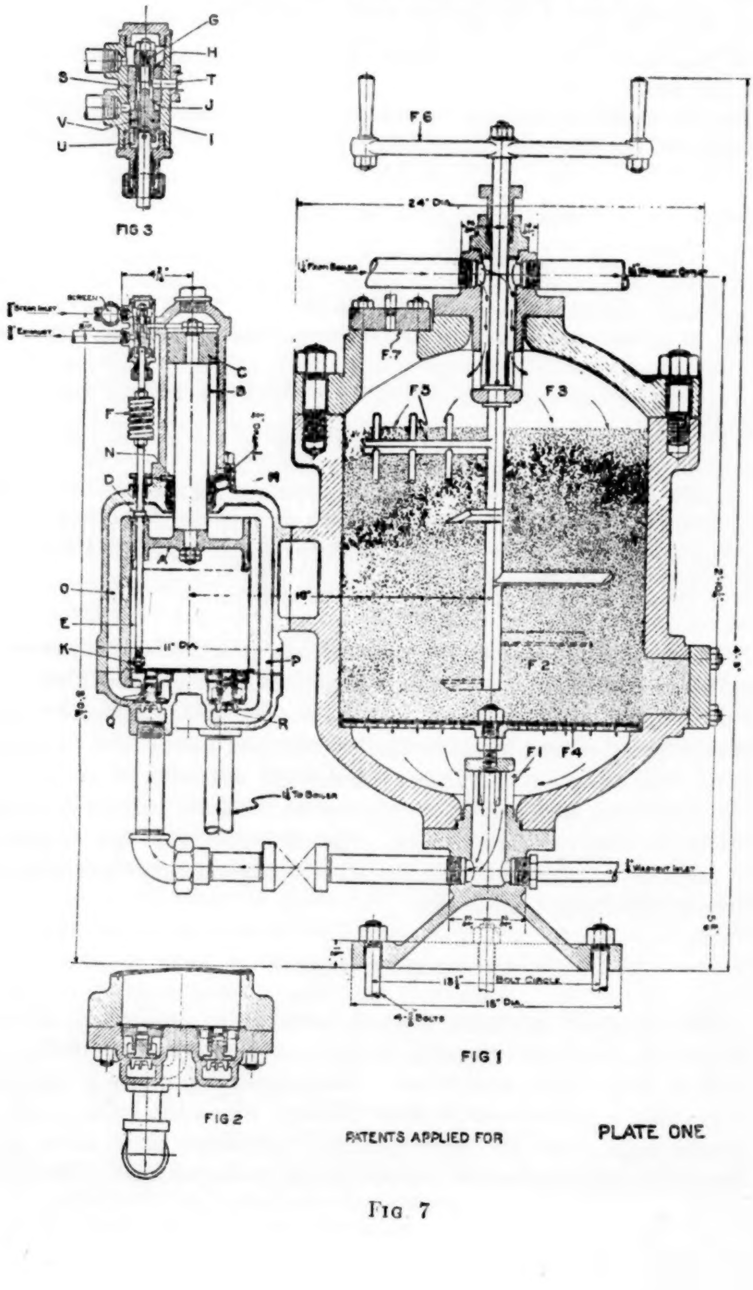

FIG. 7

concentrator" is under boiler temperature and pressure, but a small pump is necessary to overcome friction losses due to passage of the water through the piping system and filter sand. The effluent from the deconcentrator, after the scale-forming substances are removed by the filter, is discharged into the boiler. By this treatment a large percentage of the scale-forming matter is filtered from the water as it is formed, instead of depositing on the tubes. When the filter becomes clogged by the deposits of scale-forming substances on the surface of the sand, the unit is cut out of service and washed by reversal of the flow of water, as is done in back-washing other types of pressure filters.

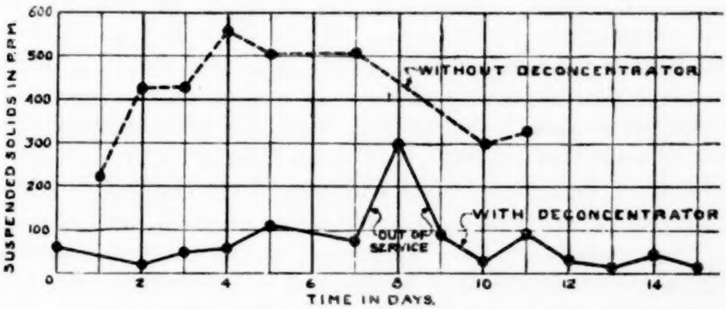

FIG. 8. SUSPENDED SOLIDS IN WATER FROM TWO STEAM BOILERS, ONE WITH AND THE OTHER WITHOUT HAGAN DECONCENTRATOR

The method is novel in that the heat of the boiler is utilized to precipitate the lime and magnesium salts and there is no material loss of heat, as the filtered water is returned to the boiler. This arrangement does not prevent accumulation of sodium salts and other constituents which are not precipitated readily by heat. For this reason, blowing down of the boilers will be necessary whenever there is a high concentration of soluble salts in the boiler water.

A test of this apparatus was made recently at a large power station, the results of which are given in figure 8. These data demonstrate what may be accomplished by removal of the scale-forming ingredients from boiler water supplies by this apparatus. Like many others that have been used, the system is not a "cure-all," but has a peculiar usefulness in limiting scale formation, where a more elaborate system could not be installed with economy.

EVAPORATION

Distilling water for use in steam boilers is the most efficient method for the removal of suspended or soluble solids. Distilling plants—or evaporator systems, as they are termed generally—have not been employed widely, but this method is coming into favor in power-plant practice. Several types of evaporators have been designed and the art of distilling water has reached a high state of development. This equipment is relatively costly, however, and so far has been used only in boiler-plant installations where the exhaust steam is condensed in surface condensers and where the makeup water is only a small percentage of the gross consumption of the plant. Evaporator installations, not including erection cost and other construction requirements, will cost from $600 to $1000 per 1000 pounds per hour capacity. The total first cost of a modern plant will double possibly the cost of equipment. Ordinarily the percentage of water for make-up in a modern power station, where surface condensers are used, will range from 2 to 10 per cent, or even higher, depending on the efficiency of the condensing system. It will not be economical to purify water generally for boiler feed use by evaporation, if the amount of water to be treated is in excess of 25 per cent of the total boiler-water requirements. At steam stations where salt or brackish water must be used, evaporation is the only method of treatment satisfactory for the elimination of the soluble solids.

Distilled water is particularly corrosive to metal and where evaporators have been used to purify water for boiler use, corrosion troubles at times have been experienced. In some instances these difficulties have been overcome by degassing the make-up water, or employing other corrective measures.

The value of evaporators for treatment of boiler water and the saving effected by such a system are manifold. There are many intangible items that affect the gross saving, which are not apparent from station records, but these will be enumerated specifically later.

Distilled water for use in steam boilers is the ideal method for maintaining a clean boiler. The tendency of modern boiler-room practice is toward higher boiler rating and greater overall economy of operation. If these conditions are to be fulfilled it is essential that the losses due to poor feed water shall be eliminated. The adop-

tion of the evaporator to accomplish this purpose is an engineering problem and must be determined by local operating conditions. The features in favor of or for the rejection of evaporators for power-plant work have been summarized by the Committee on Boiler Feed Water of the Prime Movers Committee of the National Electric Light Association. These are given verbatim in the following statement:

The features favoring an evaporator installation are essentially those which apply in the case of a water treating plant with a few exceptions or additions, but may be enumerated as follows:

(1) Practical elimination of boiler blowdown, which ranges from one to three per cent of the total feed water. Except for condenser leakage it would doubtless be possible to eliminate entirely the boiler blowdown.

(2) Improvement in heat transfer due to elimination of scale. As pointed out in the discussion under water treating plants, this item is frequently overestimated but will doubtless lie somewhere between one and three per cent.

(3) Operation of the boilers over longer periods of time, thereby causing savings in labor and power for cleaning; in losses due to shutting down and starting up of boilers; in idle boiler investment while being cleaned; and in tube replacements and boiler repairs. The necessity for taking the boilers down for stoker and furnace repairs more frequently than for boiler cleaning would detract somewhat from these savings.

(4) Low operating cost. The operation of the evaporator is automatic. The largest labor item is for cleaning. No chemicals or other operating supplies are required. Aside from labor, the only appreciable operating charge is for heat losses due to radiation and evaporator blowdown. It is roughly estimated that the radiation loss will run about two British thermal units per pound of water of hourly evaporator capacity. The blow down loss allowing 13 per cent blow down will run about 20 British thermal units per pound of water evaporated.

(5) Perhaps the largest item in favor of an evaporator installation is the fact that it eliminates almost entirely and permanently bad feed water troubles and their derivatives from all consideration in connection with continuity of boiler plant service, plant economy, high boiler ratings, turbine blading erosion and miscellaneous trouble aggravated by bad feed water.

The disadvantages of evaporators may be enumerated as follows:

(1) Distortion of plant heat balance unless the entire electrical and steam driven auxiliary system is laid out for the use of evaporators. The low thermal loss of an evaporator system depends on the fact that the latent heat of the vapor from one "effect" is used either as live steam in the next or for heating the feed water above 210 degrees in a closed feed water heater, or to 210 degrees in an open feed water heater. Each "effect" used reduces the amount of vapor to be disposed of and consequently the amount of heat balance distortion, but increases proportionately the first cost of the equipment. The

"two effect" system with vapor from the second effect going to the feed water heater seems to be the more common layout for generating stations.

(2) High first cost which, by way of illustration, ranges for a complete "two effect" installation of around 10,000 pounds to 15,000 pounds hourly capacity, between $13,000 and $16,000, respectively. If the proportion of make-up to total feed water runs much over 8 or 9 per cent, either the heat balance distortion is very great or the installation cost due to additional effects and perhaps a closed heater makes the cost of installation correspondingly high. Consequently there is an economic point somewhere around 10 per cent of make-up beyond which it does not pay to put in evaporators except perhaps in very special cases.

(3) Due to the expense of providing evaporator capacity, it is especially desirable that a minimum of condensate or feed water be wasted; as for example in the hot well overflow or the feed water heater overflow. Ample hot well surge capacity is very necessary. On the other hand, if there are appreciable leakages of raw water into the feed water system through condenser leakage, sealing glands, etc., the fine advantages of an evaporator system are correspondingly diminished. Plants using sea water or otherwise very bad water for condensing purpose should investigate this phase of the situation carefully.

METHODS FOR DEGASSING WATER

A number of theories have been advanced during recent years to account for the corrosion of metal by water. In all these theories consideration has been given to dissolved gases, principally oxygen, as a contributing agent. Cushman has demonstrated clearly the fact that dissolved oxygen is responsible to a large degree for corrosion of iron and steel and if this gas is removed from the water the corrosiveness of the water is reduced greatly. The experimental data presented by Cushman have been verified frequently in the operation of steam boilers, economizers and other auxiliaries at a number of large power stations. Figure 9 shows graphically the accelerating effect of dissolved oxygen in water on corrosion. These data were obtained a short time ago by the writer in experimental studies of the corrosion of steel coils through which aerated water was circulated for cooling in oil transformers. Special studies of considerable magnitude have been made recently at several plants in this country in order to devise methods to exhaust dissolved gases completely from boiler feed supplies. The two methods that have received the most attention from investigators are the removal of dissolved gases by heat or by passing over iron. Both methods are applicable to power-plant use.

REMOVAL OF GASES BY HEAT

With the exception of carbon dioxide the amount of gases dissolved by water is dependent upon the temperature and pressure. By heating water up to the boiling point a high per cent of dissolved gases will be released. In open feed-water heaters, if the temperature of the water is raised to 200° Fahrenheit, or higher, most of the oxygen can be expelled. It has been claimed by several authorities that 0.5 cc. of oxygen per liter is a safe maximum limit at which the

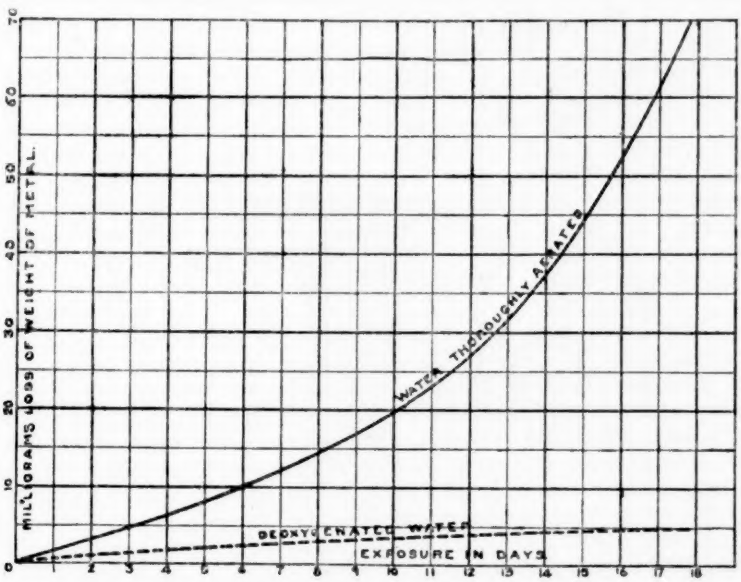

Fig. 9. Effect of Oxygen on Corrosion of Steel Tubing

oxygen content of the water may be maintained without serious danger from corrosion. Other investigators believe that corrosion caused by oxygen cannot be prevented unless this gas is reduced to 0.2 cc. per liter, or a less amount. The removal of the last trace of air cannot be effected generally in open heaters. To accomplish complete removal of oxygen it is necessary to heat the water in vacuum.

In the Elliott Process the removal of dissolved oxygen and other gases is accomplished by flashing the heated feed water into a partial vacuum. By this method, if the apparatus is operated efficiently

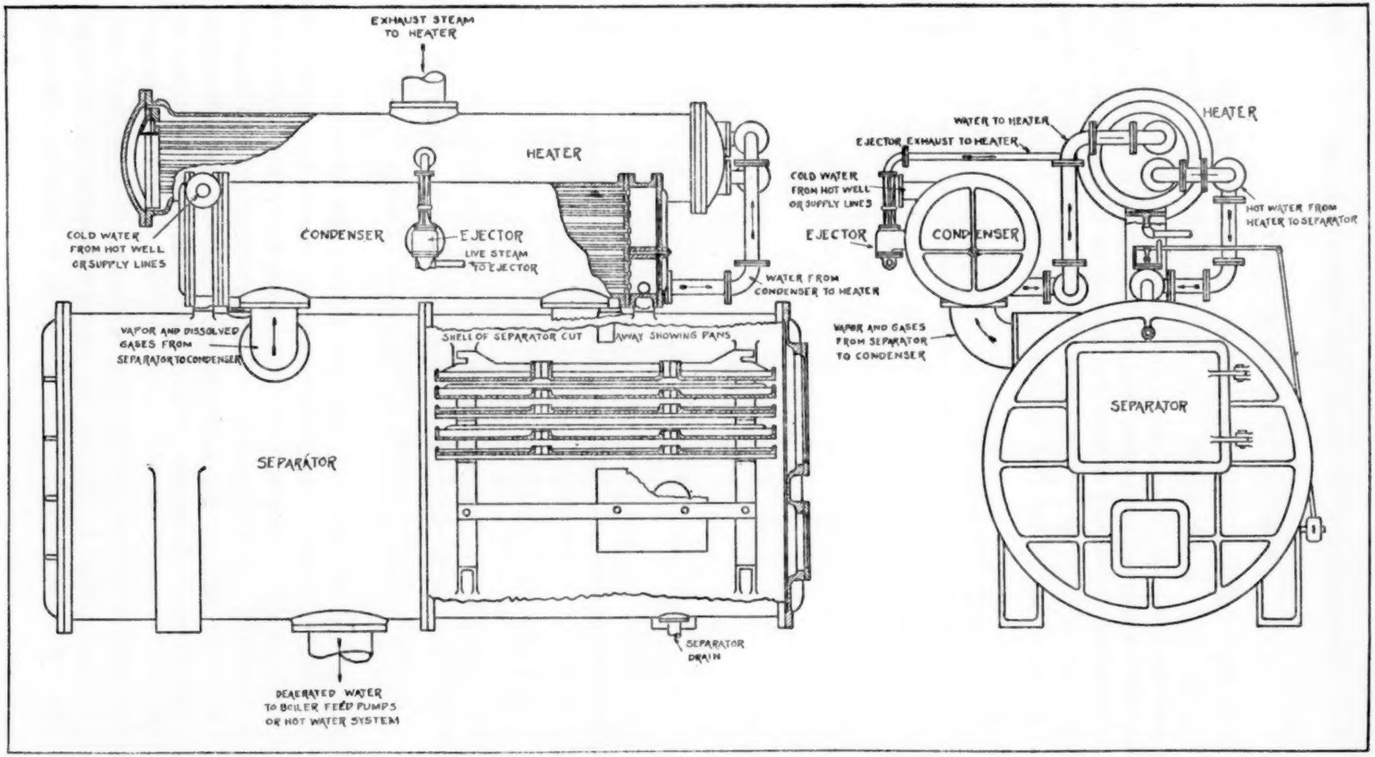

FIG. 10. ELLIOTT DEAERATOR

and a tight system is maintained, there is practically 100 per cent elimination of gases. Figure 10 shows the Elliott Deaerator. This apparatus operates in the following manner:

The water enters the Condenser attached to the Deaerator from the supply main, and makes the passes through the cooling circuit. In making these water passes it picks up all the heat from the explosive boiling which is taking place in the Deaerator, and for every pound of water which enters the Deaerator, there is an equal amount passing through the circulation of the Condenser, since the two are in series. The cooling water in the Condenser, therefore, picks up the heat from the boiling process and from the Condenser flows to the Heater, taking the heat along with it. In the Heater it is heated to some predetermined temperature, and then admitted under gravity flow to the Separator. In the Separator there is a vacuum maintained which will be 22° at least below the temperature of the entering water. The two temperatures are so correlated that this relationship always exists.

When the water enters the Separator, it is superheated in relation to the vapor space that it enters. It, therefore, boils suddenly, since the heat is already available to accomplish the boiling and there is a partial disintegration. After the water has been partially pulverized, it flows over pans made in a stepped arrangement to give maximum agitation, and then flows down into the water space, where it is stored for a few minutes ready to deliver to the supply.

The Condenser which was mentioned as the first piece of apparatus in the path of the flow is significant from three standpoints. It, first, recovers the heat of the explosive boiling, and the process amounts to a continuous circulation of heat from a higher to a lower temperature, but no heat is wasted. The Condenser, further, recovers the vapors from the boiling process, and returns them back through the stream of steam into the Separator, thus saving all the water. Finally, it separates the condensable vapors from the non-condensable gases, and permits the evacuating means to handle only non-condensable vapors, thus lightening the duty of this device. The Ejector steam, amounting, in the average domestic installation, to about one pound to every ten thousand pounds of water handled, is returned to the closed heater and there condensed. The apparatus is, therefore, 100 per cent thermally efficient.

REMOVAL OF OXYGEN BY IRON

The use of iron for the removal of oxygen from water has been practiced for many years, but recently studies have been made and special apparatus has been developed assuring more dependable and efficient operation. The process is purely a chemical phenomenon which, according to Gaston, may take place in the following manner:

THEORY OF DIRECT ACTION

There are three oxides of iron which can be formed through direct action with oxygen; and in the presence of water these oxides give the corresponding

hydrates. These oxides correspond to three different states in the complete action.

1. The iron combines with oxygen to give black ferrous oxide FeO, in accordance with the following equation:

$$Fe + O = FeO$$

and $FeO + H_2O = Fe(OH)_2$ hydrate of ferrous oxide, flaky and unadhering to iron.

2. Ferrous oxide combines with oxygen to form the black saline oxide Fe_3O_4, in accordance with the following equation:

$$3\ FeO + O = Fe_3O_4$$

and $Fe(OH)_2 + H_2O + O = Fe_3(OH)_8$ hydrate of black saline oxide, which adheres to iron.

3. The black saline oxide combines with oxygen to give the red ferric oxide, Fe_2O_3, in accordance with the equation:

$$2\ Fe_3O_4 + O = 3\ Fe_2O_3$$

and $2\ Fe_3(OH)_8 + H_2O + O = 6\ Fe(OH)_3$ the hydrate of red ferric oxide, which adheres to iron.

When oxygen is in excess the action can take place directly from the iron to the hydrate of red ferric oxide without going through the intermediate stages.

$$2\ Fe + 3H_2O + 3\ O = 2\ Fe(OH)_3$$

In either case a layer of rust ($Fe(OH)_3$) is formed on the iron.

In practice it is customary to heat the water first to eliminate the oxygen that can be driven off by this means, then to pass the partially degasified water over iron turnings where practically complete removal of the oxygen will take place. Kestner reported recently that this action is accelerated by the presence of manganese. This condition is shown in figure 11. No great number of large installations of this kind for degasifying boiler feed water have been made, but the method has been adopted by many smaller heating plants.

The removal of dissolved gases may have another beneficial effect in power plants in addition to the prevention of corrosion. In steam stations using surface condensers it is necessary to maintain the dissolved gases at the minimum if the heat transfer is to be maintained effectively. The condensation of steam in surface condensers depends on the conduction of heat from the steam through the walls of the condenser tubes and transferred from the metal to the circulating water. If, therefore, gases have not been exhausted from the water before entering the boiler they may be carried over into the condenser. Released in the condenser tubes, they form a film which is interposed between the steam vapor and the surface of the metal. Under this condition there must be a transfer of heat from the steam, through the air film and from here to the metal. Removal of air

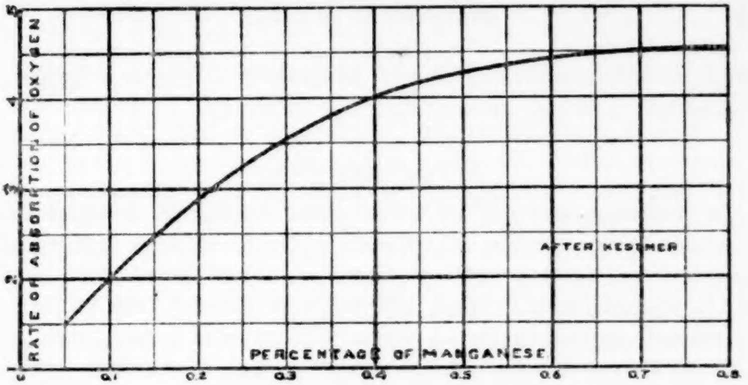

Fig. 11. Increase in Rate of Absorption of Oxygen with Increased Manganese Content in Iron over Which Heated Water Passed

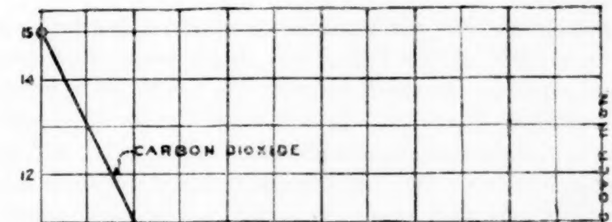

Fig. 12. Reduction in Dissolved Oxygen and Carbon Dioxide by Passage of Heated Water over Iron

effect, therefore, not only lessens corrosion in boilers and appurtenances but increases surface condenser efficiency.

BOILER COMPOUNDS

In reviewing methods of boiler water treatment, consideration should be given to boiler compounds. The use of boiler compounds does not constitute a water-purification method in the strict sense of the meaning of this term, but boiler compounds are employed so extensively that their use demands more than passing mention.

There are operators who believe that no chemical should be applied to water within the boiler, as any corrective treatment should take place outside the boiler. Others believe that boiler compound will accomplish all that is necessary to eliminate scale formation or prevent corrosion.

It is preferable that the purification of water for boiler use be carried on outside of the boiler, but under some conditions it is necessary frequently to choose between the use of boiler compounds and no treatment whatever. In such cases the use of compounds is advisable and, if properly chosen and discreetly applied, will improve operating conditions. In small plants boiler compounds are used promiscuously but with uncertain results. These compounds consist usually of some form of soda salts together with organic matter. Generally the purchaser pays a very high price for a cheap article which has been given a fancy name. There are a great many different compounds on the market today, ranging from pure frauds to carefully prepared substances. Of the better grades offered to the trade, many will give satisfactory results if used properly. One kind of compound which is widely heralded by the manufacturers is that which forms gelatinous deposits in the boiler. These substances consist generally of soda together with organic matter, principally gelatine or gums. The value of these substances consists in prevention of scale by the formation of jellylike substances about the lime and magnesium salts, as these constituents are thrown out of solution in the boiler. This kind of compound deposits a jelly film upon the tube instead of scale. The loss of heat due to the film is high, as will be noted from the results obtained in tests made by the writer, given in figure 13. The only saving to be effected by a substance of this kind is the prevention of scale, but this saving is offset by loss of heat and losses that may be caused by corrosion, burned tubes or "bagged boilers."

There has come to the writer's attention recently a serious case of corrosion in all four drums of a boiler where a compound of this kind was used. The evidence in the case was conclusive that the pitting in the boiler was due entirely to the use of the compound, as it occurred in only one boiler in the entire battery, and this

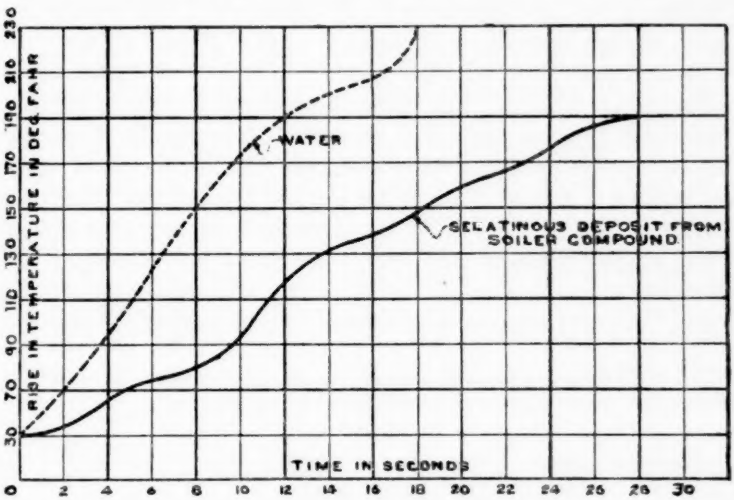

FIG. 13. LOSS OF HEAT DUE TO GELATINOUS COMPOUNDS

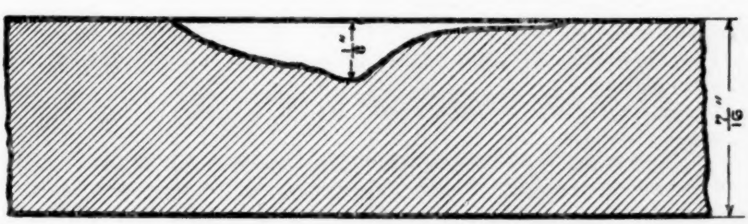

FIG. 14. METAL CORRODED AWAY FROM BOILER PLATE BY USE OF BOILER COMPOUND

Sectional view of boiler plate. Corrosion 28 per cent

boiler was the only one in which the compound had been used. All boilers had used the same feed water and had been under similar duty. The corrosion was in the form of pitting and the pit holes were very deep, as will be seen from figure 14.

The only explanation of the case that seems possible is that the jelly formation adhering to the surface of the metal produced an

acid reaction, due to the breaking down of the organic substances contained in it and these started active corrosion of the metal.

TREATMENT OF WATER FOR RAILROADS

It is the aspiration of all steam railroad operators to increase the tonnage moved per locomotive. To accomplish this requires good water, as high locomotive efficiency is vitally affected by the quality of water used. The principal method of water treatment used by railroads is softening. The plants are either of the intermittent or continuous type of lime-soda softeners. Thousands of plants of this kind are in operation daily along the lines of numerous railroads and billions of gallons of water are purified annually by these plants. The great majority of these softeners are situated in the Middle West, where extremely hard waters are found. A statement of the operation of the treatment plants of the Missouri-Pacific Railroad during 1920 is of interest, as it represents a characteristic example.

In reference to water treatment plants for the year 1920

AMOUNT INVESTED IN TREATING FACILITIES	QUANTITY WATER TREATED	SCALING SOLIDS REMOVED	TOTAL SAVING	COST OF TREATMENT SUPERVISION, 10 PER CENT DEPRECIATION	NET SAVING
	gallons	*pounds*			
Eastern district— 11 plants, $4,498	497,662,000	1,384,197	$155,597	$35,624	$119,963
Western district— 52 plants, $176,303	730,611,000	2,084,237	310,694	75,304	235,390
Southern district— 4 plants, $26,400	389,087,000	1,049,449	158,417	32,641	215,776
Total system— 67 plants, $244,201	1,617,360,000	4,517,883	624,708	143,579	481,129

The total saving indicated above, represents 197 per cent of the amount invested in water treating facilities.

The total consumption of water on the system during 1920 was 6,526,826,000 gallons, of which 5,618,665,000 gallons were used for making steam, and of this amount 28.8 per cent was treated. The average cost of treatment in 1920, including operation, 10 per cent on the investment in treating facilities for depreciation, and of supervision, was 8.87 cents per 1000 gallons, compared to 8.72 cents in 1919; 6.57 cents in 1918; and 4.71 cents in 1917; the increase in cost being due to the increased cost of chemicals and labor.

STATEMENT OF THE MISSOURI-PACIFIC RAILROAD

A statement of this kind requires no argument to prove the wisdom of installing water-treatment plants for the purification of water for boiler feed in locomotives.

Considerable difficulty is experienced at times from foaming and priming, due to concentration of alkali salts. With this kind of water considerable supervision of the treatment plants is required or additional chemicals must be added to the water in the boilers in order to eliminate the trouble. One road in the Middle West, using about 1,000,000,000 gallons of water annually in the boilers of its locomotives, required slightly over 500 barrels of anti-foaming compound during the year 1920, in order to correct this condition.

Many roads are forced to use water from surface streams which at times carry a considerable amount of suspended matter, mostly mud or clay. The general practice where such waters are encountered is to remove the gross amount of suspended matter by means of settling tanks, depending on sedimentation alone. Railroad practice in this respect provides generally merely a large tank, or possibly a pair of tanks, and in some instances a two-compartment tank, where the water is settled for a given period of time before being taken into the boilers. In some installations the flow of water in the tank is continuous and the only clarification obtained is accomplished by skimming the water from the upper portion of the tank by means of floating pipe. Installations of this kind are operated seldom at maximum efficiency, but even under these conditions they effect a considerable saving by removing the gross amount of suspended solids from the water.

Corrosive action of waters when used in steam boilers may be due to several causes. The presence of dissolved gases in water, acid water from mine drainage or from sewage pollution are all contributing factors.

The territories in the Pittsburgh District and in the mining districts of Virginia and West Virginia are notable for their bad water supplies. The losses to railroads using water from these territories each year run into staggering figures. Mr. Young in his paper read before this Section in May, 1921, estimated that the losses due to bad water in two railroads in the East were $800,000 annually. A large proportion of these losses are due primarily to acid waters.

Corrective treatment for waters containing free acid is probably one of the most serious problems to be encountered in boiler feed practice, especially in railroad work.

The purification of water for use in locomotives results in saving in a number of ways that possibly are not apparent readily, excepting to those who have given special study to this problem. The various factors entering into these savings are as follows:

1. Less fuel consumed per ton-mile.
2. Less repairs of boilers.
3. Fewer blowdowns of boilers.
4. Longer life of flues, fire boxes, et cetera.
5. Less delays and failures due to leaky flues and sheets.
6. Less overtime for crews.
7. Fewer cars set off and fewer trains given up.
8. Greater evaporation of water per pound of fuel consumed.

Scale-forming solids or corrosive substances are the objectionable qualities encountered most frequently in waters to be used in boilers. Some waters, however, possess still other objectionable ingredients which may cause serious operating difficulties. Under the latter class are waters that cause priming or foaming or result in the embrittlement of metal. These difficulties, although encountered less frequently than other bad water troubles in steam plant practice, present serious problems and often are more difficult to correct.

PRIMING

Priming is the term applied to the phenomena which occur when the water in steam boilers is ejected from the boiler with the steam. This condition may occur as the result of several factors. The presence of large quantities of soluble soda salts, in addition to suspended solids, the type of boiler, and the rate at which it is operated, are conditions that may bring about priming. The principal cause of priming is the presence of sodium salts. The maximum concentration at which priming will result varies with local operating conditions and other ingredients in the water in addition to the soda salts. It may be stated, however, that a concentration of sodium sulphate between 200 to 300 grains per gallon unquestionably will cause priming. Oil carried into the boiler, either from sewage waste or from reciprocating engines, is also objectionable and, like suspended matter, accelerates greatly the tendency of boiler water to prime.

FOAMING

Foaming of water in boilers under steaming conditions is the formation of bubbles on the surface of the water and in the steam space in the drums. The conditions favorable for foaming are much the same as those which cause priming. Water containing sewage or other organic waste in large quantities, especially in the presence of high concentration of soda salts, is highly objectionable on account of the tendency to foam. Where it is necessary to use water of this kind, foaming or priming may be prevented or at least corrected to a marked degree by frequent blowing down, either by surface or bottom blowoff valves.

Priming and foaming frequently result from improper operation of softening plants due to after precipitation of the lime salts in the boiler and to high soda concentration. Operating troubles of this kind may be corrected by better control of the softening system and by maintaining a lower concentration of sodium salts.

CAUSTIC EMBRITTLEMENT

Caustic embrittlement of metal is the development of fine cracks in boiler plates below the water line. These cracks form at the seams and rivet holes. Although no great number of boiler failures due to embrittlement have occurred, there has been a sufficient number of such disasters to attract marked attention. Within the past few years a number of investigations have been made in order to determine the causes of embrittlement. The conclusions reached by the majority of investigators are that the embrittlement or crystallization of metal of boiler plate is caused by the absorption of hydrogen, given off by the decomposition of caustic soda under the high pressure and temperature within the boiler. It is considered generally that the occlusion of hydrogen by the metal, resulting in embrittlement, has been found only where the boiler water contained high caustic soda and in the absence of sulphates or other salts which inhibit the liberation of hydrogen.

Some investigators have claimed that embrittlement is the result of internal strains in the metal due to operating conditions of the boiler, and not to the concentration of caustic soda. Internal strains in the metal exert probably some effect on the crystallization of metal, but the result of the studies on this subject made within the past year prove fairly conclusively that caustic soda under certain

conditions is unquestionably the primary causative agent of embrittlement. The treatment of water to eliminate embrittlement of metal has not been developed for practical use. Where embrittlement is experienced it is advisable, if possible, to secure a new water supply. The addition of magnesium sulphate to the water has been advised, as it has been demonstrated that such treatment will reduce, if not entirely eliminate, the absorption of hydrogen by the metal. The neutralization of the alkali by means of acid has also been suggested, but the danger of this treatment is too great to permit of such a procedure, excepting where exact control may be maintained.

LAUNDRY WATER

Enormous volumes of water are used daily in the laundries of the country. With the exception of water purification plants for boiler feed use, no single industry has as many water treatment plants in in use. The quantity of water for laundry work is of vital importance and influences directly the operation costs of such establishments. The water should be free from suspended matter, and of appreciable amounts of iron or manganese and of lime or magnesium salts. Turbid waters are objectionable because clothes cannot be washed or rinsed thoroughly in such water. Iron and manganese are objectionable, because these constituents when precipitated cause yellow stains upon white or light colored clothes. Aeration, followed by filtration, often will correct such trouble, although more elaborate treatment plants are required to remove iron and manganese from some waters.

Lime and magnesium salts are the most objectionable constituents in water used for laundries. These salts react with the soap to form insoluble lime and magnesium soaps, "curds," which deposit on the surface of the cloth. These precipitates depositing in the fibre of the materials reduce their life and cause streaks and stains in the laundered goods.

The soap consumed in laundries depends on the method of plant operation, but is proportional generally to the hardness of the water used. The saving effected by a softening plant depends upon the efficacy of the system in the removal of the hardening salts.

In table 1 are given the percentages of reduction in soap, soda and water after the installation of zeolite softeners in twelve laundries. These laundries operated with water of varying hardness and the percentage of rough and finished work was different at each establishment.

TABLE 1

NAME AND LOCATION OF LAUNDRY	HARDNESS	WITHOUT ZEOLITE SOFTENER			WITH ZEOLITE SOFTENER*			PER CENT SAVING		
		Soap	Soda	Water	Soap	Soda	Water	Soap	Soda	Water
	grains per gallon	*pounds*	*pounds*	*gallons*	*pounds*	*pounds*	*gallons*			
Snow White Laundry, Wilmington, Del.	3½	400	760	130,290	150	200	95,000	62	73	14
City Star Laundry, Harrisburg, Pa.	5	772	1110	269,115	318	470	226,650	59	57	15
American Laundry, Grand Rapids, Mich.	7	973	2350	318,000	350	960	263,000	64	59	17
Walkers Laundry, Niagara Falls, N. Y.	7	400	1120	192,000	96	145	100,000	76	87	48
Yale Laundry, Washington, D. C.	7	621	640	347,112	255	280	179,500	59	56	48
Kennedy Laundry, Chicago, Ill.	8	1872	3557	418,356	671	1008	172,296	64	71	59
Olean Palace Laundry, Olean, N. Y.	9	170	675	102,000	48	190	72,000	72	86	29
Westminster Laundry, St. Louis, Mo.	9	750	510	210,800	250	150	145,000	66	70	31
Cascade Laundry, Great Falls, Mon.	10	580	730	134,600	153	110	54,000	73	85	59
Imperial Laundry, Alberquerque, N. M.	10	800	1400	199,100	132	250	149,000	83	82	25
Crown Laundry, Indianapolis, Ind.	19	954	1200	224,000	502	240	154,600	47	80	31
Perfection Laundry, Springfield, O.	20	682	910	156,780	224	164	58,634	67	82	62
Average								66	74	36

* Permutit Systems were used in all these laundries.

In figure 15 is shown the saving of soap due to the reduction of hardness per 1000 gallons of water used.

From the foregoing figures, it will be seen that complete removal of lime and magnesium salts is highly desirable in the reduction of soap and soda. For this reason zeolite softeners have been adopted as a standard of water treatment in a large number of laundries, and the value of this method of treatment of water has been demonstrated repeatedly. The adoption of the method for softening water for laundries is dependent largely upon the kind of water to be treated and, as has been stated previously, the advisability of using

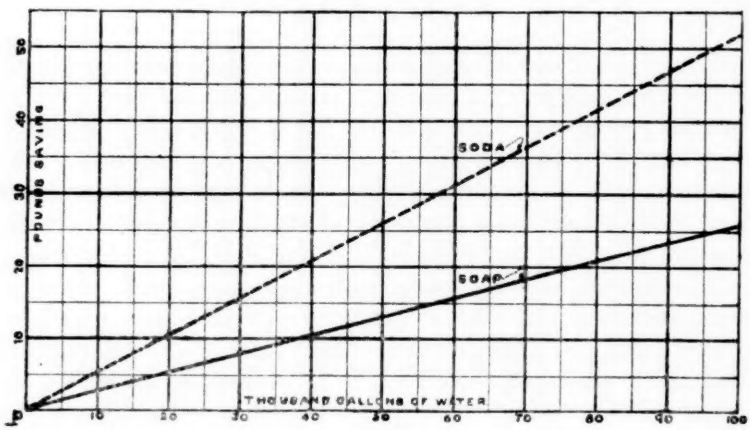

FIG. 15. SAVING IN POUNDS OF SOAP AND SODA PER 1000 GALLONS OF WATER TREATED FOR EACH GRAIN OF HARDNESS REDUCED

Average of 12 zeolite softeners

the method for this purpose should be determined by local operating conditions.

Lime and soda softeners have been used for many years for softening water for laundries and, in many localities where hard waters are to be found, the practice of employing such treatment is still common.

PAPER INDUSTRY

The manufacture of paper has been practiced for centuries and is one of the oldest of the known industries, dating back several thousand years before the Christian Era. Paper is manufactured from many different raw materials but principally from cotton,

linen, wood fibre or straws. In 1919 this industry was the ninth largest in the United States.

There are several processes employed in the manufacture of paper but all these require large quantities of water at different stages of manufacture. The amount of water required per ton of paper made will vary from as low as 10,000 gallons to nearly 500,000 gallons.

Water used in the cheaper grades of dark colored paper does not require generally any special purification, but for white and light colored paper of the finer grades the quality of the water is of great importance. Waters containing iron may not be used, as the alkalis employed for digestion of the pulp will precipitate the iron as hydroxide, staining the pulp brown or causing other defects in the finished product. Turbid water will have much the same effect as iron in darkening the white pulp. Hard waters are objectionable in the sizing process as chemical reactions take place between the lime and magnesium salts in the water and the chemicals used for sizing, resulting in paper of poor quality. Waters containing free acid are highly objectionable, as such waters interfere greatly by setting up chemical reactions, producing poor colors and streaks in the finished product. Acid water may corrode also the paper making machinery.

Water purification, principally filtration, has been practiced in the paper industry for many years. It is interesting to note in this connection that the present state of development of mechanical filtration resulted from the early experimental studies in filtration to clarify water rapidly and efficiently for use in paper mills. The Hyatt Patent, upon which mechanical filtration is based, was for this purpose.

Softening water has been employed fairly extensively for preparing water for paper mills and, with the exception of filtration, is the process most widely employed for this work. Lime-soda softeners have been used most frequently, although zeolite softening plants are being adopted at many places. Water of zero hardness, as obtained by zeolite softeners, is ideal for paper mill work where high grades of paper are manufactured.

Water purification as practiced in paper mills is much the same as in municipal work, and often the filtration or softening system is a large scale operation, purifying several million gallons of water daily.

TEXTILE INDUSTRY

The quality of water used in the woolen and other textile industries is of the greatest importance. In the cleaning or scouring of wool

large volumes of water are required. The quality demanded for this purpose is much the same as for laundry use and the water purification methods are similar. Hard waters are objectionable in wool scouring, as they consume unnecessary amounts of soap and the insoluble "curds" formed by such waters stick to the fibre of the wool, making final rinsings difficult. Silica or other suspended matter contained in water is objectionable, as it will cling to the fibre, as the insoluble soaps formed when hard water is employed. For this reason, waters with surface washings or polluted by sewage or trade wastes are not suited for use in this industry unless purified.

In some wool working processes the potash removed from the wool is recovered. Where recoveries of this kind are made it is desirable to use as pure water as possible, in order that the reclaimed potash is not contaminated from salts dissolved in the wash water.

The quality of water for the scouring of wool is practically the same as that required for preparing silk and cotton fabrics. Hard waters act the same in treatment of cotton and silk as with wool fibre, and are objectionable on account of the formation of the insoluble lime and magnesium soaps. These soaps form "curdy precipitates" and are even more objectionable in the treatment of silk fibre than of wool. The deposits of lime or magnesium cause several serious defects in the manufacture of silk goods, one of the most objectionable being the uneven absorption of the tin solution in the weighting process. This condition results in uneven or streaked dyeing.

In the cotton industry practically the same difficulty is to be experienced with hard water as in the treatment of silk.

Managers of textile mills have recognized for a long time the value of soft water and many water treatment plants are in operation. Filters and lime-soda softeners have been employed extensively in the past, and zeolite softeners are being employed widely at the present time. Many mills have adopted a combination of a lime-soda and a zeolite process. Hard water may be reduced by the lime-soda method to 3 or 4 grains per gallon, and may then be softened completely by passage through a zeolite softener. The saving to be effected by double treatment of this kind is warranted frequently, as the consumption of soap may be reduced 50 per cent or more by the use of "zero hard" water. It is conceded generally that textiles washed and scoured with water that has been completely softened dye more evenly, the colors are brighter and the finished product is softer.

TANNING

The tanning of leather is largely a chemical process employing fats, oils, waxes and vegetable and aniline dyes. Water for this purpose should contain no constituent which will cause the waste of tanning materials or interfere with the reactions involved. Hard waters are most objectionable, as the lime and magnesium salts cause losses due to the precipitation of dye stuffs. The use of such waters causes uneven and incomplete dyeing. Many leathers are given a treatment known to the trade as "stuffing." This consists in treating or stuffing the tanned hides with oils, fats or waxes. Proper emulsification and penetration of the greases into the hides does not result if hard waters are used, as the lime and magnesium unite with these oils and form insoluble compounds.

Softening by means of lime, either as a complete treatment or a combined lime-zeolite process, will result in improved product.

MANUFACTURE OF CHEMICALS

The kind of water required for the manufacture of chemicals depends upon the products to be made.

For commercial sulfuric acid, nitric acid and other heavy chemicals which are used in large quantities in various manufacturing establishments, no special treatment is required for water entering into these products, other than to remove suspended solids. Wherever possible, well waters are used and, with the exception of iron or manganese, such waters are generally free from suspended solids.

Water entering into the manufacture of high grade chemicals as used for medicinal or reagent purposes must be practically free from suspended or soluble solids. For this reason the water used for such purposes is distilled. The distilling plants are frequently of large capacity. Many types of distilling apparatus are employed for this kind of service, but evaporators similar to those used for power plant work have been installed and operated successfully.

MANUFACTURE OF ICE

Water for this purpose should contain no suspended solids or color and should not be contaminated with sewage or industrial wastes. If contaminated water is to be used for making ice it

should be filtered or sterilized. Bacteriological investigation has shown that, although there is diminution of organisms due to freezing water, some types will survive for long periods at low temperatures.

Filtration and sterilization are employed widely by ice manufacturers in order to obtain water that is satisfactory from a physical and bacteriological standpoint. Waters containing iron or other constituents which may precipitate during the process of manufacture are objectionable, owing to the appearance of the ice when waters containing these substances are frozen. Much trouble has been experienced in chlorine treated waters. Under some conditions chlorinated waters used for this purpose have imparted a disagreeable taste, which has persisted even after the water has been distilled.

Hard waters are used frequently in this industry, but a better product is obtained usually if soft water is employed. Softening plants have been installed in some places and distilled water for artificial ice making is used extensively. This method of treatment, although much more costly than any other process, is the most satisfactory treatment.

Deaerating plants have been installed in some ice manufacturing plants for the removal of dissolved gases. When degassed waters are frozen the ice produced is much clearer than with waters containing dissolved gases.

Several ingenious methods of purification have been used by ice manufacturers to produce clear ice from turbid waters, without installing water purification systems. Two of these methods are worthy of mention. In the phenomenon of freezing water the ice crystals as they form push the impurities away so that the foreign matter is found at the outer surface of the ice as it is frozen. In artificial ice manufacturing plants water is frozen generally in rectangular cans, freezing first on the outer surface, thus pushing the impurities in the water toward the center of the can. For this reason most of the contaminated ice will be found in the core of the cake. Some manufacturers remove this core and then fill the hole with water and refreeze the cake. By this method the ice is freed from foreign matter and blocks of crystal ice are produced. Another method of removing the impurities is to exhaust the gases from the water as the cake is frozen. During this process much of the foreign matter is carried to the top of the cake and may be removed from the block of ice after it is taken from the can.

NON-ALCOHOLIC BEVERAGES

During the last few years the non-alcoholic or soft drink industry has grown rapidly. Water for this purpose must be clear and free from bacterial contamination. Many of the modern plants have installed filters and sterilization systems to produce satisfactory water. Chemical treatment for the sterilization of water supplies is not practiced widely, as trouble is experienced at times from tastes and odors where chemicals are used for this purpose. Sterilization by ultra violet ray or by ozone has been adopted in many modern plants. Sand filters and charcoal filters are also used extensively. In many of the larger cities where filtered water is available soft drink manufacturers have installed charcoal filters as the use of this type of filter insures a clear, sparkling effluent. The danger from the use of this type of filter is that, if not operated properly, bacterial growths may occur in the bed. This trouble has not been a serious hindrance to the manufacturers of soft drinks, as generally where these filters have been installed the effluent is sterilized. Hard waters are not objectionable for this industry, provided that they do not deposit solids on standing.

CONCLUSIONS

The brief review of some of the needs for water purification in the industrial field, considered in this paper, impresses one with the vast opportunities for scientific study in this field. Little advance has been made in the purification of industrial waters within the past twenty years, primarily because of the failure to recognize the problems in industrial application and particularly because of the lack of interest which such problems excite. During the past few years there has appeared an increasing interest in the physical and colloidal phenomena of water purification. The field of industrial treatment presents an almost endless series of problems, the solution of which depends in many cases upon detailed investigation of the colloidal properties of water and of the application of methods of treatment based upon the laws of physical chemistry. The formation of scale, the corrosion and the embrittlement of metal and the action of water in dyeing or bleaching processes present an excellent field for constructive water purification research.

DISCUSSION

J. R. McDermet:[4] The paper by Mr. Powell this evening has claimed the speaker's immediate attention, particularly those sections relating to boiled waters, which are of the greatest commercial importance. From an industrial standpoint, boiler water problems have always harassed the engineer and come within his particular duty. The engineer has not had the insight into this particular province, which was necessary for its successful solution, and he has applied to water problems certain arbitrary criteria which were not necessarily founded upon the refined technology of the chemist. Boiler water problems are of significance to the speaker as an engineer, and the paper and, in particular, its presentation before such a Society as this is an augury of future rapid developments and co-operation between engineers and chemists.

The paper is a commentary upon various ways of practicing the art of securing satisfactory industrial water. Certain sections of it, notably those relating to zeolite softening and the use of gelatinous boiler compounds, are distinct and original contributions to existing knowledge. Mr. Powell has also summarized, in a most admirable manner, material which has appeared in the French technical press on the degassing of water by the corrosion of iron. This material needed very urgently to be brought to the attention of American technologists and its original publication was obscure and not readily accessible.

In Mr. Powell's discussion of coagulating chambers and coagulants, the writer, knowing Mr. Powell personally, has been able to assume what he omitted to emphasize, viz: that the use of coagulants on boiler waters requires very careful chemical supervision and is not a process which a novice should use indiscriminately. Coagulants are uniformly of such a composition that they incorporate a cation, having a high atomic weight and a high electric charge and they are also of the class which are designated as amphoteric, forming variously acid or alkaline salts under different conditions. Their indiscriminate use may cause very nasty corrosion.

The speaker cannot agree with Mr. Powell that a zeolite softener is generally advantageous as a boiler water treatment. There are certain classes of water which, from an excess of carbon dioxide over the carbonate and bicarbonate content, are found to be intensely

[4] Research Engineer, The Elliott Corporation, Jeannette, Pa.

corrosive. Zeolite treatment augments this corrosive property. Water softened by zeolite treatment, invariably after being concentrated in the boiler, is of high sodium alkalinity. It lies, therefore, in the range which produces caustic embrittlement of the boiler plates and it is practically impossible to operate efficiently a boiler on zeolite water without bringing the contents of the boiler within this hydrogen embrittlement range. This form of boiler plate destruction is demanding increased attention from boiler operators and is making itself formidably felt. The primary cause of this recent attention is of course the use of zeolized water and the consequent damage to boilers.

Mr. Powell's comments that zeolite softeners will deliver water which is non-scaling in a boiler is undoubtedly true, but the other conditions of use are such that a slight amount of scaling would be useful. In addition, the zeolized waters of normal hardness have a higher solubility for dissolved gases than the natural water, preliminary to passing through the zeolite. It is probable, however, that the zeolite softener within the ranges which Mr. Powell designates as economically feasible, has a very wide field of usefulness in small boiler plants employing 100 per cent make-up. While it is not free from suspicion and is certainly not an ideal way of securing a good boiler water, it is far better than the evils which it corrects and, from that standpoint, is very useful. Its successful use, from a corrosion standpoint, however, is, in the writer's experience, predicated very much upon locality of application.

Zero hardness and zero soap consuming power have been very much confused by the zeolite manufacturers. Zeolized water, certainly when properly treated, can be made zero soap destroying, and its use in laundries and textile plants is attended with high economy.

In presenting the facts in connection with the use of evaporators, Mr. Powell, in the speaker's opinion, should have emphasized the fact that the distillate from the commercial power station evaporator is appreciably different from the distilled water of the chemical laboratory. The average performance of an evaporator is never much less than five to eight parts per million scale forming solid. This, however, as Mr. Powell states, is not sufficient in quantity to produce scaling.

The tendency among the present boiler operators is to throw an increasing amount of absorption of the heat by the boiler surfaces

upon the first tube bank, to which the heat is transmitted in radiant form. These tubes perhaps comprise, at the most, 25 per cent of the area, but the heat absorption within them is sometimes 60 per cent of the total heat absorbed by the boiler. It is imperative that these tubes be kept scrupulously clean; otherwise, with the terrific heat transferred, bagging and blistering results. It would appear reasonable, therefore, to assume that, as boiler ratings are increased along the present tendencies, the use of water containing, say, less than eight parts per million of scale forming materials is imperative. This seems to be approximately the limit below which the boiler waters will not form scale. The presence of dissolved solids is significant only in the ebullition phenomena within the boiler.

S. T. Powell:[2] The author was interested in reading Mr. McDermet's discussion of this paper. Mr. McDermet has emphasized the necessity of careful supervision of feed water treatment. This point is well taken, as poor operation of systems for the treatment of boiler water may lead to serious results. Whenever it is necessary to apply chemicals to boiler water, careful control is essential and can not be neglected without danger of injury to the boilers or to other steam station equipment.

The writer regrets if he has conveyed the idea that zeolite water softeners constitute a universal method of boiler feed water treatment or are a cure-all for all boiler water problems. This treatment of feed water has a wide application, however, as is evidenced by the results obtained in a large number of installations. Softening water by zeolite, due to the nature of the process, causes a concentration of soda salts within the boiler and softening excessively hard water by this treatment may cause boiler operating difficulties from high soda concentration. The treatment of soft or medium hard water by zeolite will not cause excess soda concentration when used in a steam boiler, if the boilers are blown down at frequent periods. High caustic soda alkalinity is unquestionably one of the main factors in causing metal of boilers to embrittle, but the results of recent studies show that this phenomenon takes place only under special conditions. The sub-committee, on the treatment of boiler feed water, of the Prime Movers' Committee of the National Electric Light Association, has given the following statement in respect to this condition:

In connection with this subject, a practical question of moment is whether the use of sodium carbonate for treating feed water is likely to lead to this trouble. Nothing in the investigative work which has been thus far done indicates danger unless the result of treatment yields a water which finally, in the boiler, has what, from the operating point of view, would be high concentration of sodium hydroxide and almost entire absence of other substances.

Embrittlement of boiler plates has happened in a number of cases but these failures are by no means a common occurrence. There are great numbers of boilers which have been operated for years using water high in soda salts, without any evidence of embrittlement, so that high soda concentration alone will not account for this phenomenon. For this reason, I can not agree with Mr. McDermet when he states "The primary cause of this recent attention is, of course, the use of zeolized water and the consequent damage to boiler." Boiler corrosion has been experienced in some cases after the installation of zeolite softeners. These conditions have occurred invariably when dissolved gases have not been removed from the treated water. Rapid corrosion may take place with comparatively small amounts of dissolved oxygen or carbon dioxide gas, if the gases come in direct contact with the metal. With complete elimination of scale forming salts, resulting from zeolite softening, the tubes and drum of boiler receive no protection, due to scale, from these corroding gases. It is essential, therefore, in using zeolite softened water for boiler feed to reduce the dissolved gases to a minimum.

ROBERT SPURR WESTON:[5] Mr. Powell's admirable summary of the art of industrial water purification calls attention to an interesting work in a field which has needed cultivation, for in spite of the reports to engineering societies, water works associations, and railway maintenance of way associations, data are few and practices are far from standardized.

Particularly valuable for engineers engaged in this field are the data obtained at the Westport Steam Power Station. Unlike the records of performance of most industrial purification plants, they cover working conditions and a considerable period of time. Most information regarding such plants comes from short-time tests of well-tuned apparatus, often operated by others than those in permanent charge. Mr. Powell's data include costs which increase their value.

[5] Of Weston and Sampson, Consulting Engineers, Boston, Mass.

Insofar as chemical reaction formulae can express them, Mr. Powell has explained what goes on in the softening process. While beyond the scope of his paper, he might have added that these reactions are not so simple as the formulae. The physico-chemical laws come into play, and with them mass action, equilibrium, and the like. Reagents must usually be added in excess to produce reactions, and often such an apparently insoluble substance as chalk has an annoying way sometimes of remaining in colloidal suspension rather than coagulating and precipitating out of solution, as the formulae would indicate.

I was particularly interested in the descriptions of modern devices, as deconcentrators, zeolite softeners, and deoxygenators. Zeolite softeners, as engineers well know, are not of universal application and must not be prostituted to uses beyond their powers. They are neither filters nor good deferrization plants. If so used, the action of the zeolite is brought to an end by occlusion.

I am one of those who believe that a steam boiler is a poor reaction chamber for boiler compounds, and that most boiler compounds consist of simple substances sold at too high prices. Yet with their aid some power plant operators keep their boilers remarkably clean. One clever chief engineer in Camden, N. J. keeps his boilers clean by using in turn the waters of the polluted Delaware River, the aerated municipal ground water supply, and water from a deep well, the latter containing over 200 parts of free CO_2 per million, besides iron and manganese. Evidently he uses one water until it begins to form scale, another to dissolve the scale, and still another to inhibit corrosion.

If, as is now believed, embrittlement of boiler plates is produced by an excess of caustic soda, is not the best corrective carbon dioxide, and is not the best source the gases from the stack of the plant whose boilers are being embrittled? Decausticization by CO_2 is now practiced in at least three municipal water purification plants and the process is worthy of extension to industrial plants.

Mr. Powell has made clear that each water is a problem by itself and that scientific operation is as important as careful design of the structures. If his paper stimulates engineers and particularly large corporations to purchase those purifying devices indicated by a study of the water rather than because of the efficiency of the sales department, the art will have been advanced measurably.

BIBLIOGRAPHY

SPELLER, FRANK: Control of Corrosion by Deaeration of Water, Jour. Franklin Institute, April, 1922.

WITHAM, SR. G. S.,: Modern Pulp and Paper Making, Chemical Catalogue Company, 1920.

DE LACOUX, H.: Industrial Uses of Water, D. Van Nostrand, 1903.

SUTERMEISTER, EDWIN: Chemistry of Pulp and Paper Industry, John Wiley & Sons, 1920.

Heine Safety Boiler Company: Steam Boiler Engineering, 1920.

CUSHMAN AND GARDNER: Corrosion and Preservation of Iron and Steel, McGraw-Hill Company, 1910.

ROGERS, A.: Manual of Industrial Chemistry, D. Van Nostrand, 1921.

H. S. B. W. Cochrane Corporation: The Sorge-Cochrane Hot-Process Water Softener.

The Prime Mover Report: National Electric Light Association, 1920; National Electric Light Association, 1921; National Electric Light Association, 1922.

KRIEGSHEIN, H.: Power, April 27, 1920.

McDERMET, J. R.: The Separation of Dissolved Gases from Water, American Society of Mechanical Engineers, 1920.

PAUL, J. H.: Boiler Chemistry and Feed Water Supplies, Longmans-Green & Co., 1920.

A Comparison of Various Methods of Water Purification, Chem. & Met. Eng., Jan. 19, 1921.

Water Softening Results on Two Railroads, Railway Maintenance Engineering, Oct., 1921.

Hagen Deconcentrator, Bulletin, 1922.

TURBO-CENTRIFUGAL PUMPS[1]

By C. R. Waller[2]

The construction and design of a turbo-centrifugal pumping unit are known unquestionably to everyone interested in this paper. It is not my intention, therefore, to give any detailed description of such a design.

The purpose of this paper is to discuss certain features of a turbo-centrifugal pumping unit, which will allow the engineer to judge better the merits of such a unit and compare it with pumping units of other designs.

When considering pumping plants for a municipality, it is important to be able to analyze, with a fair degree of accuracy, the cost of operating and maintaining the proposed plant.

If we go back about ten years, we find that most municipal pumping plants consisted of triple expansion or compound engine driven pumping units. Units of this design have been in use for twenty to thirty years. Much data have been obtained which have helped the engineer to estimate accurately operating costs and maintenance for any new undertaking.

When a turbo-centrifugal pumping unit is considered, few data are available for the engineer's service, and he is, in many cases, at a loss to know how to arrive at a true cost covering operation or maintenance.

The items to be considered in the development of a new pumping plant or remodeling an old are original investment of land, buildings and equipment and yearly operating cost, consisting of interest charges on original investment, amortization charges, repairs, maintenance, labor and fuel.

The items of land, buildings and equipment, constituting original investment, are primarily dependent upon the number of units involved. Land and building charges in many cases are affected by location of the pumping plant and by its artistic value to the

[1] Paper presented before the Philadelphia Convention, May 18, 1922.

[2] Chief Engineer, De Laval Steam Turbine Company, Trenton, N. J.

community. It is impossible, therefore, in this paper to give any approximate cost covering the items of land and buildings.

To arrive at an approximate cost of a main unit and its auxiliaries, I have selected data collected from publicly opened municipal bids. These figures indicate that the cost of units for 150 feet total head will vary from sixty to forty-five dollars per horse power for rated capacities from 10 million gallons per day to 100 million gallons per day; and for units for 250 feet total head the price would vary from fifty to forty dollars per horse power for rated capacities from 10 million gallons per day to 100 million gallons per day. The above figures do not include erection or any part of the boiler plant.

The weight of a geared turbo-centrifugal pumping unit built for 150 feet total head will vary from 50,000 pounds for 10 million gallons per day rating to 200,000 pounds for 100 million gallons per day rating; and for units built for 250 feet total head from 60,000 pounds for 10 million gallons per day rating to 300,000 pounds for 100 million gallons per day rating.

In establishing the yearly operating cost, the first question to be settled is—What is the life of a pumping unit? When judging a triple expansion engine unit, it has been the practice in the past to consider the life of such a unit as long as thirty to forty years, whereas, for a centrifugal geared turbine driven unit, some engineers have figured as low as ten years, the most common figure having been twenty years.

The life of thirty to forty years assumed for a triple expansion pumping engine may be correct, if it is only a question of keeping the unit in operation for pumping water. Practice has shown, however, that in many modern municipal pumping plants, twenty years and even less has been the actual life of the triple expansion engine units, not because the units have been worn out, but due to the fact that they have become obsolete. I believe also that I am correct in stating that, considering the cost of pumping water, it would pay to replace about 75 per cent of all triple expansion pumping units in service more than twenty years.

From the above it would seem that the assumption of a useful life of thirty to forty years for a triple expansion pumping engine is too long and that twenty-five years would be more correct.

What is the life of a geared turbine centrifugal pumping unit? To my knowledge, this type of equipment has not yet been in service long enough to determine accurately its ultimate life. It is necessary,

therefore, to analyze more carefully some of the main parts involved, in order to determine for estimating purposes a fair life of an equipment of this nature.

A geared turbine centrifugal pumping unit is composed of three parts, each constituting practically an individual unit, that is, a steam turbine, a gear reduction and a centrifugal pump.

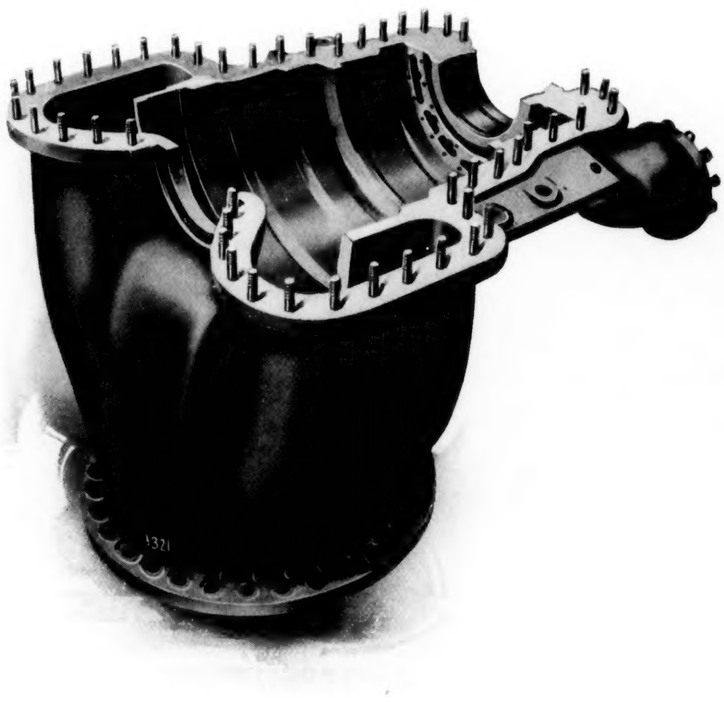

FIG. 1. WHEEL CASE OF DE LAVAL MULTI-STAGE STEAM TURBINE

Steam turbines have been used for the last thirty years. Their more universal adoption as a prime mover dates back fifteen to twenty years. There are many turbines operating today which have been in continuous service for over twenty years.

A steam turbine is composed of stationary elements and a rotating element. The turbine case and cover enclose the vital working parts of the turbine. The part of the casing which comes in contact with steam under boiler pressure is made of cast steel, the remaining portion of the casing and cover being made of cast iron. There is

nothing in connection with the turbine case and cover that can wear out, and consequently their life is not limited. The stationary elements inside of the turbine casing are called diaphragms and the openings formed in the diaphragms, called nozzles, are used for directing the steam against the revolving buckets. These stationary parts may be compared with cylinders of a triple expansion engine. The nozzles in any multi-stage turbine are affected to a certain extent, by the steam flowing through the machine and they may be subjected to wear. The wear, however, except in special cases, is not any worse than the wear on steam piping and fitting in the steam line.

The revolving part of the turbine consists of a number of turbine discs with buckets mounted on a shaft, the buckets constituting the only part which may have to be replaced due to wear. The turbine buckets, subjected to the impact of the steam at high velocity, may wear in time, particularly if the steam contains water or impurities. With well designed buckets and proper material, the life of the buckets in a multi-stage turbine should be between fifteen to twenty-five years. All modern steam turbines are designed so that the buckets may be replaced at little expense.

From the above, we may conclude that the life of the principal parts of a steam turbine is not limited and that any part subjected to wear may be replaced without much trouble or expense.

Let us now consider the gear reduction. The durability of a gear reduction is dependent on design, material and workmanship. If a unit is intended to operate twenty-four hours per day, three hundred and sixty-five days in the year, it is imperative that a design be used which is conservative in its proportions. The tooth pressure per inch width of gear face must be conservative and considerably lower than when a gear reduction is used for driving generators or other machinery with a fluctuating load.

The material used in the pinion and the gear must be selected so as to form the best wearing surface for the gear teeth. It must be absolutely uniform and free from internal stresses due to heat treatment, etc., in order to insure a permanent contour of gear teeth.

The workmanship must be perfect, which necessitates the use of the most accurate machinery for cutting the teeth.

The only function the gear case has to perform is to support the gear and pinion in a permanent manner. As the fundamental principal for a successful gear reduction is to maintain a fixed and permanent relation between the gear shaft and the pinion shaft,

the gear case is naturally made very heavy and rigid. The gear case and cover are not subject to wear of any nature.

The revolving parts of a gear reduction consist of the gear wheel on its shaft and the pinion shaft. Where a gear reduction is used up to its permissible limit for power transmission, slight wear may exist and the life of a pinion and gear therefore is not unlimited. From present indications, based upon careful inspection of gears which have seen continuous service of ten years, the average life of a gear reduction designed with conservative proportions should be

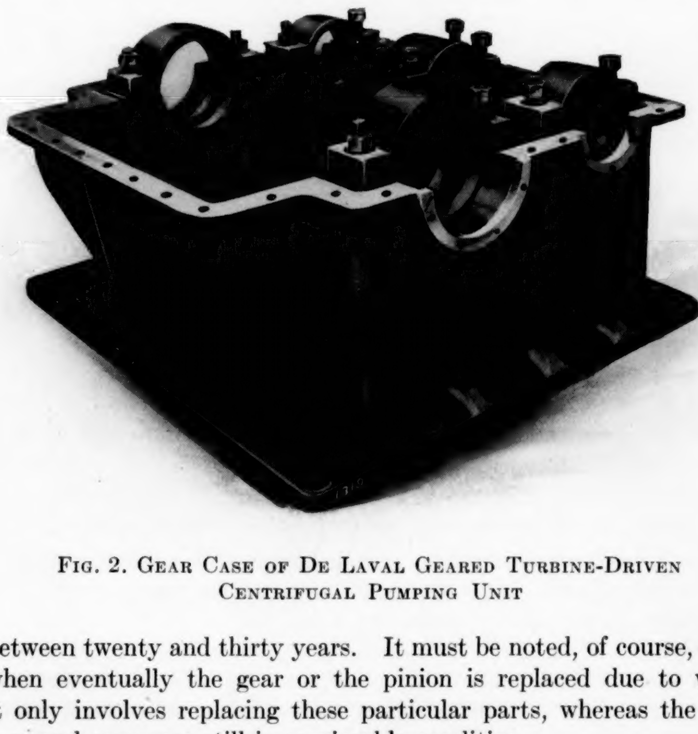

Fig. 2. Gear Case of De Laval Geared Turbine-Driven Centrifugal Pumping Unit

between twenty and thirty years. It must be noted, of course, that, when eventually the gear or the pinion is replaced due to wear, it only involves replacing these particular parts, whereas the gear case and cover are still in serviceable condition.

It may be interesting to mention in this connection that gears have been made by the De Laval Company which have been in continuous service for over thirty years. These gears were used for smaller machines than the ones discussed here, but it proves without doubt that mechanical gear reductions have been made to withstand successfully continuous service. The De Laval Company has a

number of gear reductions over 500 H.P. which have been in continuous service for not less than ten years and, from all inspections that have been made, very slight wear has been found and it has been impossible to predict the ultimate life of the gears. In some cases the pinions have shown slightly more wear than the gears. It would be fair to assume that the pinion would have to be replaced before the gear.

Let us now consider the centrifugal pump.

As has previously been brought out in connection with the turbine and the gear reduction, a centrifugal pump is also composed of a

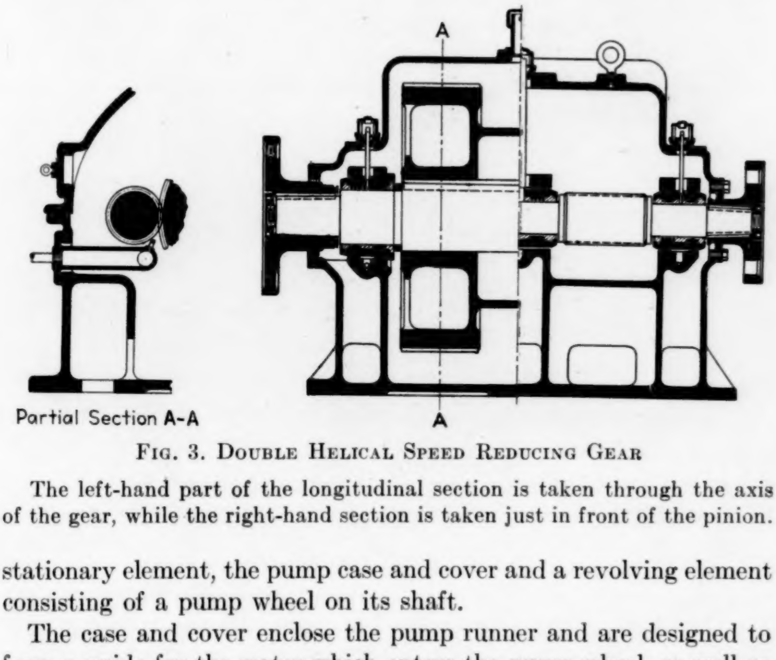

Fig. 3. Double Helical Speed Reducing Gear

The left-hand part of the longitudinal section is taken through the axis of the gear, while the right-hand section is taken just in front of the pinion.

stationary element, the pump case and cover and a revolving element consisting of a pump wheel on its shaft.

The case and cover enclose the pump runner and are designed to form a guide for the water which enters the pump wheel, as well as to receive the water which leaves the impeller. The life of a pump case and cover where clean water is handled should be at least twenty-five to thirty years. Where gritty and sandy water is handled, the pump case and cover may be subjected to wear, but due to the thickness of material used, there should be rare cases where a pump case and cover would have to be replaced due to being worn out.

The revolving parts, that is, the impeller, wearing rings and shaft sleeves are subjected to wear and must be replaced at intervals.

The life of these parts is entirely dependent upon local conditions. Where clear water is used, the only parts subject to serious wear would be the protecting sleeves and possibly the wearing rings, but even these parts should not have to be replaced often. Where the water handles sand, the wear is entirely dependent upon the percentage of solid material handled. Where the water is very bad, as

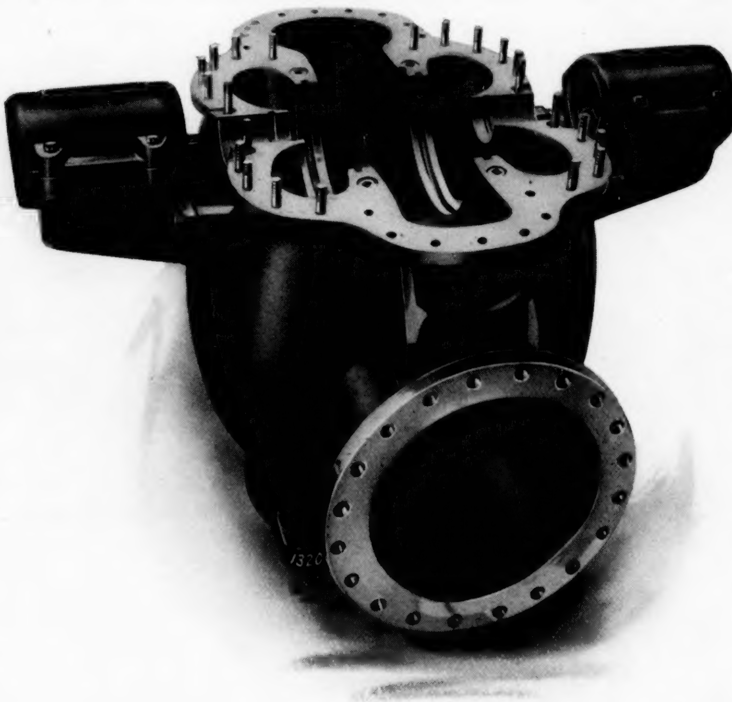

FIG. 4. PUMP CASE OF DE LAVAL CENTRIFUGAL PUMP

for instance, the Mississippi water, wearing rings may last less than two years.

In case of wear, the design of the centrifugal pump is such that the pump rotor may be removed, new shaft sleeves and wearing rings installed without any lengthy shut down.

For average water conditions it should not be necessary to replace these parts oftener than once every eight to ten years.

Summarizing what has been mentioned in connection with the turbine, the gear reduction and the pump, we find that all the major

parts are of such design and construction that they do not in any way limit the life of the equipment. We find also that all the revolving parts subjected to wear are of such design that they may be easily replaced or repaired without excessive cost. It has been pointed out that, for ordinary conditions, extensive repairs are needed only at great intervals of time.

For estimating purposes, it is safe to assume, therefore, the life of a geared turbine centrifugal pumping unit to be the same as the life assumed for a triple expansion engine unit, or twenty-five years.

The next items to be considered in connection with yearly costs for a new pumping plant are repairs and maintenance.

By repairs I mean furnishing parts which have worn out due to general wear and tear, and by maintenance, such items as lubricating oil, packing, waste, etc. When determining an average value of repairs, it is essential to assume that cost of replacement parts which would be required during the life of the machine and to distribute such cost over the assumed life of the machine. Considering the life of a unit at twenty-five years, it would be fair to consider the following list of replacement parts during that period:

Turbine

One complete set of bearings
Re-babbitting one set of bearings
One set of governor valve parts (valve discs and valve seats)
Re-bucketing the first stage turbine wheel
Two sets of carbon packings

Gear reduction

One complete set of gear bearings
Two complete sets of pinion bearings
Re-babbitting one set of bearings
One high speed pinion

Pump

One complete set of bearings
Re-babbitting one set of bearings
One pump rotor complete
Two sets of shaft sleeves
Two sets of wearing rings

Analyzing the above list of repair parts, which would constitute the average material necessary during the twenty-five year period, it has been found that the price of these parts on a yearly basis would constitute 0.45 per cent of the price of the main unit.

As mentioned above, when considering maintenance, reference is made to such material as is used when keeping a machine in service, that is, lubricating oil, shaft packing for the pumps and waste.

The quantity of lubricating oil used per year varies somewhat with different size units and depends also on the hourly operation of the unit, as well as upon the care given to the oiling system. Any good turbine oil should be satisfactory for not less than 10,000 operating hours. The quantity of oil that should be used in the oiling system for units ranging from 500 to 2000 H.P. may be approximated from the formula: $\frac{\text{H.P. rating}}{10} + 250 =$ gallons of oil in the oiling system. It is in all cases advisable that the oiling system should contain five times the amount of oil that can be circulated through the machine per minute. The oiling system referred to above is of the type where an overhead tank is used. I recommend strongly the use of an oil purifier in connection with the oiling system, as this will give the best assurance for keeping the oil in good condition.

The cost of shaft packing for a centrifugal pump should be based on replacing the packing once a year, if soft packing is used, and once in three or four years, if metallic packing is used.

Waste used by the operator and chargeable against the main pumping unit with its auxiliaries, should not exceed 10 pounds per week or approximately 500 pounds per year.

The labor charges against a pumping plant are dependent to a great measure on local conditions. When designing a new plant, it is always important to study carefully the relation between the main unit and its auxiliaries, in order to simplify the work of the attendants.

A pumping plant, with three units installed, two units for service and one for spare, should not require more than one engineer and one oiler for each shift, to keep the plant in operating condition.

It must be remembered that a geared turbo-centrifugal pumping unit is designed in such a manner that it does not need continual attention, nor does it need manual adjustment of parts as most regulating devices are automatic.

Fuel cost is of course one of the main items in the yearly operating cost of any plant where steam is used. When estimating the cost of fuel for a plant, it must be remembered that the main unit in operation is not the only place where steam is used. It is as important to consider the efficiency of the boiler plant and its auxiliaries as it is to consider the efficiency of the main unit.

In this connection, it may be well to mention that steam turbines may be modified in their design in a great many ways in order to help create the correct heat balance for a plant. By this I mean that the main pumping unit may be equipped with a turbine where steam can be admitted and extracted at pressures and quantities to establish correct heat balance in the plant.

It is an important detail to study carefully the method for driving auxiliaries for the main pumping unit. The highest plant efficiency may demand in some cases that the auxiliaries be driven from the main unit; in other cases, the use of independent non-condensing turbines, and again electric or hydraulic motors. It would be impossible in this paper to give any suggestions as to the most efficient arrangement of auxiliaries, as the problem involved requires careful analysis in each case, where local conditions and operating cycles may be carefully studied.

When making up an estimate for a new plant, the engineer may desire to compare the fuel charges for a triple expansion pumping plant with those for a geared turbo-centrifugal pumping plant. In such cases, the steam pressure, steam temperature and vacuum should be adapted to suit best the individual equipment in question. In other words, it would not be fair to figure the triple expansion engine unit with sufficient condensing equipment to produce 29 inches of vacuum, nor would it be fair to figure the duty of the turbine based on 27 inches vacuum.

To give the engineer some assistance in determining the possible duty of a geared turbo-centrifugal pumping unit, I will give some approximate efficiencies covering turbines, gears and pumps.

The efficiency of a steam turbine means the ability of the turbine to transform the available energy in the steam to useful work. Experience has shown that, to eliminate internal losses in a turbine and also to have a design where the losses will not increase with years of service, it is preferable to use multi-stage turbines. The number of stages to give the best efficiency will vary, depending upon steam conditions available, as well as upon operating speed of the turbine. It must of course be borne in mind that it is not always advisable, particularly in connection with small units, to figure on maximum turbine efficiency, as such turbines would be too expensive for the horse power involved, resulting in increased interest charges.

Based upon the Rankine cycle, the efficiency of a turbine will vary from 64 to 74 per cent depending upon the size of the unit, the steam conditions available and the permissible cost.

The efficiency of a gear reduction is very important to consider as any loss in this part of the equipment is constant. Correctly proportioned gears, well lubricated, should have an efficiency of not less than 97.5 per cent for small gear reductions and 99 per cent for larger reductions.

The efficiency of the pump depends upon the operating conditions for which it has to be designed. It is of utmost importance to keep the suction lift for the pump to a minimum, even if it is possible to design a centrifugal pump for any reasonable suction lift. The efficiency of a pump is not affected by suction lifts up to 12 feet, but above this amount the pump wheel has to be specially proportioned to take care of the increased suction lift and invariably at a sacrifice of some efficiency.

For pumps used for water works service, the pump efficiency will vary from 80 to 86 per cent, depending upon the operating conditions.

The development of the geared turbo-centrifugal pumping unit in the last ten years has been phenomenal. While ten years ago a duty of 100 million foot-pounds per 1000 pounds of steam was considered good, today units can be built with a guaranteed duty as high as 200 million foot-pounds per 1000 pounds of steam where operating conditions are favorable and where modern steam conditions prevail.

One feature in connection with a geared turbo centrifugal pumping unit that should not be overlooked is that the equipment as a whole may be erected and operated at the manufacturer's plant prior to shipment. This is, in many cases, advantageous to the purchaser, as he may satisfy himself that the unit will function in a manner as contemplated and no serious delays will occur due to mechanical difficulties after the unit has been installed.

As far as the maintenance of the efficiency is concerned, the geared turbo-centrifugal pumping unit is far superior to the reciprocating pumping unit, due to the total absence of valves in the pump end. I have seen numerous reports where the slippage of a reciprocating pump has increased rapidly in a comparatively short time, unquestionably due to trouble with the pump valves.

Through the courtesy of Mr. C. E. Davis, Chief of Bureau of Water, City of Philadelphia, I am able to give below a tabulation covering the original test of one geared turbo-centrifugal pumping unit installed at Belmont Pumping Station and also tests conducted about a month ago. The results of these tests are remarkable, when

it is considered that the tests of a month ago were run after the units had been in continuous operation for six years. The figures given were taken from tests run by the City.

	CONTRACT CONDITIONS	UNIT 4 TESTED MAY 26, 1916	UNIT 4 TESTED APRIL 4, 1922	UNIT 5 TESTED APRIL 12, 1922
Steam pressure, lbs. gauge	190	180.4	182.5	182.0
Superheat, °F	90°	126	33.5*	32.0*
Vacuum (30" bar.), in mercury	28.5	28.33	28.18	28.54
Suction lift, feet	18	16.4	18.4	18.5
Total head, feet	334	335.6	306.6	308.4
Speed of pump, R. P. M.	600	572.4	575	592
Capacity, M. G. D.	22	22.00	26.57	25 40
Capacity, G. P. M.	15,300	15,300	18,450	17,650
Duty as run, M. ft. lbs. per 1000 lbs. steam			143 1	141.6
Duty corrected to contract conditions.	150.0	151.58	153.0	151.3

* Low superheat due to changes being made in the superheaters.

It may be interesting to note in this connection that the City of Chicago made an exhaustive study a short time ago of the cost of pumping water, the investigation being made in connection with plans for a new pumping station now under contemplation. From the figures compiled, it is gratifying for the makers of geared turbo-centrifugal pumps to note that it was found that this type of pumping equipment far surpassed any other type investigated.

Through the courtesy of Mr. M. Murdock, Chief Engineer of the City of Chicago, I am able to give below a complete tabulation of the figures his engineers compiled during the investigation mentioned.

Proposed municipal pumping station—comparative estimated costs of complete station. 300 million gallons per day; 90,000 million gallons per year (300 days)

	TYPE OF PRIME MOVER			
	Steam turbine	Triple expansion engine	Diesel oil engine	Electric motor, 2300 volts
Type of pump	Centrifugal single stage	Plunger	Centrifugal 4-stage	Centrifugal single stage
Capacity of pump, M.G.D.	60	50	60	60
Total head, ft.	150	150	150	150
St. pr. at boiler, lbs. abs	330	230		
Superheat at boiler, °F	200	100		
Temp. steam at boiler, °F	626.3	493.8		
Total heat in steam at boiler, B.t.u	1322.2	1260.7		
St. pr. at throttle, lbs. abs	315	215		
Superheat at throttle, °F	200	100		
Total heat of steam at throttle, B.t.u	1320.8	1259		
Vacuum turb. exhaust, in Hg	28½	28		
H. P. of engine or motor, H. P.	1900 Br.	1390 Ind.	1900 Br.	1900 Br.
W. H. P. of pump W. H. P	1590	1315	1590	1590
Mechanical eff. of unit, per cent	83.5	94.5	83.5	83.5 (pump) 94 (motor)
Thermal eff. of unit, per cent	18.0	21.8	23.7	
Duty per 1000 lbs. steam, M. ft. lbs	173	205	184	
Duty per mill. B. t. u., M. ft. lbs	130	162.8		
Duty per 1000 lbs. oil, M. ft. lbs			3500	
Steam consump. per eng. H. P., lbs./hr	9.55	9.15		
Steam consump. per W. H. P., lbs./hr	11.45	9.66		
Total steam (5-turb., 6-eng.), lbs./hr	91,000	76,200		

Total steam for aux., lbs./hr	27,300	23,000		
Total steam reqd., lbs./hr	118,300	99,200		
Factor of evaporation	1.18	1.115		
Total steam reqd. from and at 212°F, lbs./hr	140,000	111,000		
Total boiler H. P., H. P.	4,060	3,200		
Eff. of boiler, per cent	70	70		
Heat in coal, B. t. u.	11,500	11,500		
Coal reqd. per 24 hr., tons	204	160.8		
Coal reqd. per 300 days, tons	61,200	48,240		
Heat in oil, B. t. u.			19,000	
Total oil per 24 hr., gal			15,840	
Total oil per 300 days, gal			4,752,000	
K. W. H. per 24 hr.				213,750
K. W. H. per 300 days				64,125,000
Original investment:				
Cost of land	$52,072	$58,748	$32,550	$23,400
Cost of buildings	933,350	1,154,250	656,800	455,000
Cost of equipment	1,201,400	2,423,858	1,716,495	352,500
Miscellaneous	18,000	20,000	66,000 Fuel oil tank	20,000
Total investment	2,204,822	3,656,856	2,471,845	850,000
Operating costs per year:				
Cost of labor	$63,495	$89,437	$30,000	$25,680
Cost of fuel—Coal $4.00 per T., Oil $0.05 per gal	244,800	190,944	237,600	
Cost of power—$0.0064 per K. W. Hr				413,904
Cost of oil, waste, etc	3,000	15,300	20,000	5,000
Repairs and maintenance	22,624	40,616	13,700	5,280
Interest on investment and depreciation	136,600	201,700	179,385	69,200
Total operating cost	470,519	537,997	480,685	519,064

	TYPE OF PRIME MOVER			
	Steam turbine	Triple expansion engine	Diesel oil engine	Electric motor, 2300 volts
Unit costs:				
Unit cost of labor per million gallons	$0.71	$1.00	$0.33	$0.285
Unit cost of fuel or power per million gallons	2.72	2.12	2.64	4.60
Unit cost of oil, waste, etc., per million gallons	0.03	0.17	0.23	0.056
Unit cost of repairs and maintenance per million gals	0.25	0.45	0.15	0.06
Unit cost of interest on investment and depreciation per million gals	1.52	2.24	2.00	0.77
Total cost of pumping 1 million gallons	5.23	5.98	5.34	5.77
Total cost of pumping 1 million gallons one foot high	0.0349	0.04	0.0356	0.0385

AIR AND WATER RELIEF VALVES[1]

By M. M. Borden[2]

The intent of this paper is to restate and assemble the general facts concerning the use of air and relief valves on water supply mains and to present the subject in such a manner as will promote discussion and elicit the experiences and conclusions of water works engineers and executives.

Air release, water relief, and to a considerable extent, water pressure regulating valves are essential means for automatically insuring the safety, as well as the full carrying capacity of water pipe lines.

CLASSIFICATION

These devices may be classified briefly as follows:

An air release valve may be of the type which automatically releases accumulations of air or it may be a simple cock or hydrant at the summit of a pipe line, that is opened manually when required.

An air and vacuum valve is a valve of ample area, capable of automatically admitting air when the pressure within the pipe becomes nearly that of the atmosphere and, further, of remaining open for the emission of air until the water fills the pipe line to the valve.

A combined air and vacuum valve, with air release valve, includes the foregoing two types in one setting.

A water relief valve may be either a simple pressure plate arranged to rupture at a fixed pressure or any valve or device capable of automatically opening an ample area when the pipe line pressure reaches a prescribed amount.

GENERAL FACTS ABOUT AIR IN PIPES

Air tends to accumulate in a pipe line at all points where there is a slope in both directions. More air is in solution in water in winter

[1] Presented before the Philadelphia Convention, May 18, 1922.

[2] Simplex Valve and Meter Company, Philadelphia, Pa.

than in summer. Some of the air in solution is released as the pressure is diminished and as the temperature increases. The greatest rapidity of release occurs after a vacuum has been established. A greater amount of air is found in those summits that are close to the hydraulic gradient.

As a rule, the variation in velocity occurring in a pumping main tends to make the accumulation of air at summits more gradual. On the other hand, the greater amount of air due to suction leaks or open pump connections may result in larger quantities of air in summits of pumping mains.

Less air is likely to be taken in through a gravity supply, yet the low velocity in the main that is usual and the steady flow makes its accumulation on such pipe summits more considerable.

Every sharp change in direction of the pipe line is a matter of suspicion with regard to air accumulation. Long, nearly level stretches of pipe, as along a river bank or canal, may have troublesome points for air accumulation where such pipe lines dip under sewers, tunnels, streams, or other obstructions.

Water mains working under pressure of 50 pounds or less need to be studied carefully with regard to the need of air release valves, in particular, those summits nearest the source of supply or where the pressure is least, should be considered carefully. The effect of an accumulation of air at a pipe line summit is two-fold. The operating head is reduced in amount by the height of the air bubble and the area of discharge at the reduced velocity is further diminished or may be entirely cut off. It is remarkable how an air-bound summit will retard the flow of water, even to complete shut-off. Where the pressure head is but a few feet, an insignificant summit may stop the flow as completely as a closed valve and a summit of only one diameter of pipe may constitute such an elastic barrier as to reduce the effective area of the main, as sand and gravel accumulations in a looped portion of the pipe will do.

Some examples of the delicate nature of these air summit problems were referred to in an article by J. W. Ledoux, read before the New England Water Works Association, November 10, 1920.

It may be stated, as a general proposition, that lead jointed water mains working under a pressure of 150 pounds or upward, will allow air to leak through the caulking material. Air will escape through crevices through which water will not go. In fact, serious leaks may follow the washing out of fine particles of caulking material

that would otherwise remain in place if the pipe were filled with water.

Air in a pipe line is further the cause of great damage caused by the sudden change in position of a quantity of trapped air, resulting from a change in velocity. The resultant displacement of the water, with the effects that follow from high velocity and great momentum, become serious matters, particularly in long sections of gently sloping pipe.

The cushioning effect of air in mains is helpful against water hammer, but this advantage does not compensate for the damage resulting from the unexpected change in position of such air accumulations.

APPLICATIONS

The foregoing remarks refer particularly to the conditions requiring automatic air release valves.

The function of such a valve is, therefore, to draw off accumulations of air. The necessity for their use exists whether the supply main is small or large.

Air valves are viewed usually as intended for mains under positive pressures only. Troublesome accumulations of air, however, on suction lines have been removed by them. In such cases, the air valves have their discharge openings connected to an air receiver from which air is periodically exhausted by suitable means.

In the case of pumping lines, it has been found helpful to place air valves with ample discharging capacity close to the pumping engine in order to take away air which might later give serious trouble should it accumulate elsewhere on the piping system and suddenly change its position.

Except in unusual cases, air release valves do not require large air discharging orifices. As a rule, only one valve at the summit is sufficient. Where unusual quantities of air are to be removed, the valve may be provided with larger openings or may be placed in clusters of two or more.

A method which is more economical as to the cost of the valve, includes the mounting on the top of the pipe, of a storage chamber of larger diameter, which would be ample enough to catch and retain irregular processions of air bubbles that would follow along the pipe. This allows a single air valve sufficient time to release this trapped air at a constant average rate. Such a storage chamber

may be part of the valve body, at the expense of a larger stop valve placed between it and the pipe line.

The prime requirements for air release valves for such purposes are:

Large power to insure the opening of the valve against a high internal pressure.

A valve seat of such a form that will be least liable to stick shut or to leak water.

An operating float that will not corrode, collapse or become disconnected from its lever.

Material that will not deteriorate on account of corrosion.

Simplicity of construction, easy bearings, few parts.

A valve that may be shipped with a minimum probability of damage and that may be placed in service without necessity for dismantling or assembly in the field.

A design that shall embody ease of access for repairs and replacement of minor parts, should these ever be required.

Designs that have proved their reliability by use for many years show the following elements: A valve seat, a buoyant float, and (in the best types) an ample leverage between float and valve.

The valve seat may be of hard brass or other dependable lasting material and the valve of brass or bronze, both of a design that will give greatest insurance against sticking.

Floats have been furnished of wood, cork, brass, copper, hard rubber and glass. In some cases air release valves have been designed wherein the float member contained water or was of solid metal, floating in water.

Different designs of valves will of course suit different conditions best. A higher first cost might not always seem to be warranted, but experience may prove that the most expensive type is the best in the end, since the first cost and the resultant overhead charge for a suitable number of dependable air valves is a small item when compared with the safety and capacity of the pipe line.

As air accumulates, the resultant lowering of the float opens the vent and the rise of the water closes it. Some early designs of valves had the float directly connected to the valve. In such cases the opening was of necessity small, or else there was insufficient maring for opening, when valves were used under considerable pressure. In most cases a suitable leverage is applied to the valve and the float then needs only to move a greater distance to insure operation of the valve.

It is difficult to give well-defined rules for the size of air release valve opening, connections and their spacing. Much depends upon the engineer's judgement and the conditions of the problem. Certainly an air valve should go wherever there is a major summit, and where, even in a long, gentle slope of pipe, air would do damage if it should accumulate and then be suddenly released.

If one can determine the amount of air to be handled, it is a comparatively easy matter to determine the size of opening and the number of valves required. With this in view, the table below may prove convenient for reference. Its values are close enough for estimating and are based on the assumption that the temperature inside and outside the pipe is about 62°F.

Q_m = cubic feet of air discharged per minute
D_o = diameter of air orifice in inches
$$Q_m = K \times D_o^2$$

Excess of pressure in pipe over atmospheric pressure or excess of atmospheric pressure over negative pressure in pipe in pounds per square inch

	3	4	5	7	10	15	20	25	30	35	40	45	50
K..............	134	154	172	203	241	292	334	370	402	431	456	481	503

While the air connection to the bottom of the valve casing and the air storage should be ample, economy in valve design is accomplished with safety, with respect to air releasing capacity, by the use of relatively small air orifices.

AIR AND VACUUM VALVES

The air and vacuum valve serves two purposes when used on pipes of steel, concrete or wood.

In the event of a partial or complete rupture of the pipe or of the closing of a valve at a summit while water is being delivered from the lower end of the pipe, these valves will open, and, if suitably proportioned, will allow such an inflow of air as will insure an internal pressure in the pipe that is sufficient to prevent its collapse.

The filling of the pipe is greatly facilitated and made safer on account of the release of air in large volumes and the automatic closure of the air release when the pipe is full to the valve.

In the case of cast iron mains, which may not collapse, it would be as well if such air and vacuum valves did not open when the lines broke, but their presence is most helpful in the act of filling such mains.

For moderate sized mains, a 1 inch valve on the outlet of a tee, placed underneath the air release valve and thus made accessible by a valve key from the ground level, is sufficient to allow ease in filling.

The filling of a large pipe line with safety calls for the best judgement and experience, accompanied by the aid of such valves and air vents to insure the liberation of air and perhaps their automatic closure.

These valves are of a different class than the air release valve, in that they are intended to handle large columns of air, to open only when the pressure falls to about that of the atmosphere, and to remain open only during the time of filling. They are emergency safety valves, as well as air release valves. Because of these facts such valves should meet these conditions with certainty:

The valve and seat must not stick together.

The valve must not be blown shut by the escaping of air under high velocity.

The operating float must not become water logged, collapse or fail to close the valve when the water reaches it.

Such valves are usually devoid of levers and the floats are of rubber, metal, glass or copper, all carefully shielded from the rush of escaping air. One type of valve may be obtained in which the float is open at one end and therefore can never collapse.

When these valves serve to release air when filling a main only, their size may be determined readily by equating their discharging capacity against the rate at which it is determined proper to fill a section of the line.

In the other case, namely, where they serve to protect a line against collapse, the calculation is a more involved one. It includes the determination of the minimum pressure which will not cause the line to collapse, the rapidity with which water may be emptied from the line, the amount of air which must be taken in to maintain this minimum internal pressure coincident with the water discharge and the proper area for the air valve or valves. Such problems require separate solution and interesting analyses of this sort may be found in water works engineering hand-books.

Air and vacuum valves may be grouped in clusters. Some of the earlier designs were extremely simple and proved entirely dependable. Simplicity of construction and the integrity of the float are the prime essentials.

COMBINATION VALVES

It is not infrequent that the presence of the air storage chamber of an air and vacuum valve is utilized for the counting of an air release valve. In some designs the two valves are included in the same casing. With such a combination, the construction provides all that can be desired for the safety of operating and filling of pipe lines.

Some engineers have adopted approximate rules for the size of air and vacuum valves, which give ample safety in average cases. For example, one is that for pipes of 20 inches in diameter, the valve seat should be not less than 3 inches in diameter and as the pipe line increases in size, these valve seats may be made 6 or even 8 inches in diameter.

PROTECTION—CARE AND MARKING

All air release valves of any type should be protected by gate valves or cocks placed between them, and the pipe line. This allows them to be mounted after the line is in service. It provides, too, that they shall be accessible for repairs or replacements. Convenient drains should be provided in the valve casings so that they may be emptied and protected against freezing, should repairs need to be made in winter weather. This has been accomplished by the use of a three-way cock under the air release valve.

Accessibility and frost-protection may be obtained by surrounding them with a short piece of cast iron pipe of suitable diameter, by a brick vault, or a concrete chamber. A frost-protection cover should be placed below the man hole cover.

The patrol of a pipe line should include occasional examination of such valves, since by operating the frost drain after closing the valve underneath, they will open. Reversing this operation will cause them to close and put them in service. Thus the entire function of the valve may be proved.

The location of such air vents, even though they be nothing but a manually operated valve, should be marked by signs or by posts in order to be available for such examination.

WATER RELIEF VALVES

In water works practice, the water relief valve is required usually as the result of a large consumer (such as a railroad) taking con-

siderable supply from the main by direct connections. Many such railroad tank valves and water cranes, when connected to long pipe lines, close quickly enough to produce disastrous pressure effects.

When possible, water should not be taken directly from the main through a crane or track tank, but the supply should go into a water tub, through a relatively small valve, which should be a controlling altitude valve of such design as will cause it to close gradually.

Where such conditions cannot be avoided in existing pipe lines, dependence must be placed upon water relief valves. An open surge tank may be used occasionally and this, if available, is highly effective. An air chamber, sufficiently large, is an excellent safety device but is open to the objection of requiring means for charging it and the probability of the escape of air into the main when the pressure is sufficiently relieved.

A device has been used on hydraulic pressure systems, which includes a piston whose motion is resisted by a spring. Such a device of sufficient capacity might serve on a water supply main.

The ordinary water relief valves with spring loads have certain defects: (*a*) tendency to stick closed; (*b*) tendency to remain open too long under the impact of the discharge water; (*c*) act of closing quickly and tending to produce water hammer.

An ideal relief valve would be one capable of opening quickly, remaining open only during the duration of the excess pressure wave, and of shutting off the supply gradually through ports of diminishing area.

The water works superintendent who has relief valves should operate them with the same fidelity as the engineer of a steam power plant who tries his steam relief valves.

It is not alone in the larger supply mains that water relief valves are necessary, but, under certain conditions, house plumbing needs to be protected again the effect of sudden closing of faucets. The particular need, however, in house plumbing systems is the protections against the increase of pressure due to the check valve behind the meter, and of over-heated boilers or water backs.

As the check valve is an essential element to protect the rubber disc of the meter, so is the relief valve equally essential to protect the plumbing system and the source of hot water.

The usual types of domestic relief valves contain a spring load or a direct weight load. The most dependable probably is a round

valve resting against a hard brass seat, with the most direct application of weight or force to keep it closed. Such valves, however, even of the best design, should be protected by screens so that when they discharge the valve seat will be clean for closing. They should be tested at frequent intervals.

PRESSURE REGULATORS

Without entering into an extended consideration of pressure regulating valves, it should be stated that these devices provide an admirable protection theoretically against excess pressure. If, however, they fail to close with sufficient rapidity, they may permit an unsafe, even though momentary, pressure to build up on the discharge side. If they close with sufficient rapidity to prevent this, they may cause serious water hammer effects on the supply side.

If the pressure change is not too rapid, their operations will be entirely dependable, except for the unavoidable wear of cup leathers and pistons. If the pipe line is large, the pressure change accomplished quickly, and the pressure reduction considerable, then a basin or standpipe for reducing the pressure is a better final solution.

In conclusion, we all will agree probably that water supply systems, involving both large and small pipes, will be subjected to less interruption and repair, if the location and design of air release and, if necessary, water relief valves are given sufficient study. These devices should be selected on the basis of simplicity of construction, ample power for operation, and provision against deterioration on account of collapse, rupture or corrosive effects.

REPORT OF COMMITTEE ON PHYSICAL STANDARDS FOR DISTRIBUTION SYSTEMS[1]

INTRODUCTION

The Committee on "Physical Standards for Distribution Systems," considers itself unfortunate in two respects:

First, up to date, never more than two of its members have been able to get together for discussion, so that what little progress we have to report is the result of correspondence unaided by personal contact—which is very poor for the interchange of ideas.

Second, our subject, as every practical water-works man knows, is a most intangible one, in spite of the highly tangible character of the principal parts of a distribution system.

Like "Topsy," a distribution system "just grows," and the records are full of instances of systems which have deferred the "growth" of their principal members until the weak spots have been pointed out by disastrous fires in a manner which could not be misunderstood.

Again, in the field of practical application of accessories and the details of design, there is great variation in practice. In some instances, this is due to widely differing local conditions which frequently are not understood outside, and, in others, to the varying shades of personal opinion on questions where the merits of decision along any given line have not yet been clearly established.

The field before the Committee is a wide one and largely virgin insofar as Standardization—or, to use Hoover's expression, "Simplified Practice"—is concerned. A full review of its needs and possibilities has been made, but in our present discussion only the more important features will be touched upon.

The Committee has reached three conclusions of general nature, as follows:

1. Certain items of terminology and definition are offered for immediate adoption to clear the atmosphere for further discussion.
2. Our knowledge of the hydraulic performance and our understanding of the economic design of a large distribution system are very hazy.

[1] Presented before the Philadelphia Convention, on May 18, 1922.

3. The Committee conceives its major function to be the collection and classification of data from the great store of information on practical matters which is scattered throughout the water works of the country. We now come before you, therefore, not in the rôle of instructors or legislators, but in sackcloth and ashes as the most humble seekers after knowledge.

TERMINOLOGY

It is felt that the looseness of our language is a contributory factor to the haziness of our conception of distribution hydraulics. The following nomenclature is recommended for immediate adoption:

1. "*Water Mains*" are the large pipes of a water-supply system, as distinguished from the smaller "Service Pipes" which are tapped into some of them for supplying water to individual consumers.

2. "*Supply Mains*" are those water mains which convey water from its source to the approximate limits of the community which is to be supplied, where the manifold branching of the "Distribution System" begins.

a. Unless the words "Raw water" are prefixed, it is understood that a supply-main conveys water in condition for consumption.

b. "*Gravity Supply Main*" is a self-explanatory term.

c. A "*Force Main*" is a supply main through which the water is pumped.

3. The "Distribution System" receives the water delivered to it by the "Supply Mains" and distributes it over the community according to the needs of the various sections.

The Distribution System includes the network of "Distribution Mains," with its fire-hydrants and gate, check, and pressure reducing valves, together with such reservoirs, water tanks and standpipes as there may be connected with it for the purpose of equalizing the draft on the supply system.

The Distribution System ends short of the "Service Connections" for individual consumers, and does not include separate "High Pressure Fire Systems," which are separately classed.

Three classes of "Distribution Mains" are recognized, as identified in the following paragraphs.

4. *Primary Feeders.* The "Primary Feeder System" is the network of large pipes with relatively wide spacing which conveys large quantities of water to various points in the system for local distribution through the smaller mains.

(Synonymous expressions from various authorities: Mains, large mains, main lines of pipe, feeders, large feeders, main feeders, arteries, main arteries.)

5. *Secondary Feeders.* The "Secondary Feeder Net" is the piping system of intermediate size which reinforces the distributor grid within the various panels of the "Primary Feeder System" and permits the concentration of the required fire draft at any point in the distributor grid.

(Synonymous expressions from various authorities: Sub-mains, branches, laterals, lateral mains.)

6. *Distributors.* The "Distributor Grid" is the grid-iron arrangement of small mains serving the individual fire hydrants and blocks of consumers.

(Synonymous expressions from various authorities: Smaller pipes, street pipes, street mains, small service mains, feeding mains, cross mains, cross-lines, minor distributors, grid-iron system.)

HYDRAULIC DESIGN AND PERFORMANCE

The design of a small system is of course readily subject to the common methods of hydraulic computation. But the system for a large city with its far-flung gridironed primary feeder system presents a different sort of problem.

The Committee feels that this subject will be further clarified by recognizing and separately considering two distinct classes of pressure drops in a large system:

a. Loss of head in the primary feeder system, varying in general with the total draft.

b. Pressure drop within a relatively small area due to concentrated draft for fire.

Regarding the economics of design of the primary feeder system, it has been suggested that the cost of delivering water to the point of entry into the distribution system should show some relation to the cost of avoiding dissipation of energy in the feeders.

A rational solution frequently results from the balancing of the cost of providing flatter gradients in the primary feeder system against the saving in booster pumping costs resulting from the reduction in size of hill-top areas where such service is needed.

In considering the economics of primary feeder design, three types of system must be recognized:

1. Gravity flow from distributing reservoir.

2. Direct pumping.

3. Delivering water through the city to a distributing reservoir on the far side.

In the latter two cases, economics will be affected by the following alternative conditions at the point of entry into the distribution system:

a. Pressure held practically constant.

b. Pressure raised during periods of maximum demand.

It is thought that the comparison of data on gradients actually employed in different cities, considered in the light of the conditions surrounding each case, will yield some information of real value.

Likewise, correlation of the results of fire-flow tests by hydrant pitot should be illuminating in regard to the design of the secondary feeder and distributor systems.

PRACTICAL DETAILS

It is only through the most complete cooperation of the membership of the Association that our Committee will be able to function, and we hope today to make the personal contact which will put vigor into our later communications with you.

The Committee has agreed on a questionary which we hope to give wide circulation. Many practical matters of controversial nature will be touched upon. You are urged to furnish us the evidence as well as the decision in your solution of such questions, to tell us "*why*" as well as "*what.*"

Following are a number of the subjects upon which the Committee seeks light. Some are in the form of statements, some are queries, but we desire to get here and now as many reactions as possible, so please make notes as we run through them of any of the subjects which particularly strike home, so that we may have them brought up for active discussion:

Cast iron pipe

1. Many cities use no cast iron pipe lighter than Class "B," Am. W. W. Assn. specifications.

2. Some of the larger cities standardize on a single heavy class of pipe for universal usage.

3. Some cities are eliminating certain of the intermediate pipe sizes, notably 10 and 20 inches.

4. Most cities now use 4 inch pipe only for house service on one side of a boulevard, paralleling a larger main on the other side for fire service; and in short dead-end alleys.

5. Experience in the breakage in service of large cast iron pipe has led most cities to avoid the use of some of the larger sizes under heavy pressure. The practice varies widely.

6. We should bring ourselves up to date in knowledge of the reduction in carrying capacity of pipe with age.

Branches and connections

7. The maximum size of main which it is considered good practice to tap for house service seems to be 16 or 20 inches; with larger mains, a second pipe is laid for house service.

8. Carrying this idea further, it seems reasonable that a minimum size of main might be fixed for direct connection to the large primary feeders.

9. There is much controversy over the maximum size of industrial or fire connection which should be permitted. We know of some large cities where the limit is 6 inches and others where the service must be 2 inches smaller than the main to which it is connected, with a limit of 10 inches; and we know of smaller cities where 10 inch connections to 10 inch mains are not uncommon.

Construction details

10. Many valuable data on the results obtained with substitutes for lead in jointing material must be in existence.

11. Bridge crossings constitute a most irritating subject. Once in a while we see a main on a bridge in a location which seems to have been prepared for it.

Cleveland's practice, standard at least in the case of large mains, is to offset the line to cross the depression out from under the bridge and abutments, using steel pipe made up of ½ inch plate.

12. Boston protects exposed pipes against freezing by wrapping with several layers of asbestos, over which is fastened a sheet iron cover.

13. Under railway tracks carrying heavy traffic, and in other locations where vibration is excessive, Boston has found flexible-joint pipe to be very satisfactory.

14. When a plug or a quarter-bend blows off, we have the subject of unbalanced pressures brought to mind.

15. Many cities test all new mains for leakage before the bell-holes are backfilled. Practice in test-pressures applied and maximum leakage allowed would be valuable. Leakage should be expressed in terms of "gallons per day per inch of diameter per mile of pipe."

Gate valves

16. Many cities are now using valves smaller than the main in lines 16 inches in diameter and larger. Where cast iron valve-boxes are used over vertical-stem valves, this practice of course makes a saving in expense for masonry vaults in addition to the cost of the valves; but, if cleaning of mains is to be anticipated, the reduced size at gates will be disconcerting.

17. New York uses only four sizes of valves for the various sizes of pipe over 12 inches in diameter.

18. The Committee makes bold to suggest that the current standard specifications for gate valves are inadequate. It deprecates the fact that many cities specify stem diameters at the outside as contrasted with the Associations measurements "at base of thread;" and does not understand why at least a stem cannot be adopted which will be uniform for all makes.

19. The regular operation of all valves of a system should be a matter of routine—especially the large valves. The frequency depends upon the character of the water handled.

20. Standard clearance diagrams for vaults for horizontal-stem valves would be useful.

21. Some people consider the enclosure of every valve in a vault to be justifiable expense.

22. Mr. McInnes of Boston favors the use of extension stems on all valves, making operation possible with a short wrench and avoiding the troubles which usually result from the filling up of the box by street dust sifting under the cover.

23. The practice of keeping large valves partially closed has been discussed frequently. The desirability of this practice is of course affected by the use of reduced-size valves and by power-operation.

Fire hydrants

24. Should not steamer-nozzles be provided on all hydrants connected to a general system, even in areas where pressure is usually sufficient for direct streams?

25. The automobile has made corner locations for hydrants somewhat hazardous. We have heard of one location that suffered three casualties in a year.

Other accessories

26. Check-valves are sometimes used in the larger mains at the dividing line between "zones" in order to furnish some measure of protection in the upper zone in case of failure of its supply. At St. Louis, check valves are removed whenever found. A check-valve is an undesirable obstruction in pipe-cleaning.

27. In some cities blow-offs are provided where conditions permit them in all mains 16 inches and larger in diameter.

28. Practice and experience with air valves, pressure-reducing valves and relief valves should be interesting.

G. Gale Dixon, *Chairman.*
J. Arthur Jensen,
E. E. Lanpher,
V. Bernard Siems,
W. Z. Smith,
Committee.

TASTES AND ODORS IN PUBLIC WATER SUPPLIES FROM DECOMPOSING ORGANIC MATTER[1]

By F. H. Waring[2]

The purpose of this paper will be to discuss briefly the occurrences of tastes and odors in public water supplies in Ohio that are taken from surface sources. Ohio has approximately 80 water supplies from surface sources, serving a population of about 2,830,000. Of these 80 supplies, 44 are from rivers and streams upon which no impounding reservoirs have been constructed, 16 are from rivers and streams temporarily held back in impounding reservoirs, and 20 are taken from Lake Erie or other natural or artificial lakes. At the present time, 56 of these surface water supplies are filtered and supply some 2,700,000 people. Eight, treated by disinfection alone, pending the installation of filter plants, serve 67,000 people. Sixteen are not treated and serve 63,000 people.

In considering the raw waters taken from surface sources it will be sufficient for the purposes of this paper to group those water supplies having relatively small impounding reservoirs on large streams, or on streams subject to heavy runoff during several months in the year, together with those supplies having no need for impounding reservoirs; and those supplies with relatively large reservoirs, or upon streams of small runoff during the greater part of the year, with those supplies derived from natural or artificial lakes.

In any discussion of odors and tastes, it should be recognized that the two senses of smell and taste are so closely associated as to merit considering them as one. It is perhaps unfortunate that determinations of these factors in water supplies are more or less unsatisfactory on account of the difficulties of expression. The personal equation largely enters into the interpretation and the standards of acceptability vary in different parts of the country. Tastes and odors in public water supplies may be due to a variety

[1] Read before the Chemical and Bacteriological Section at the Philadelphia Convention, May 19, 1922.

[2] Principal Assistant Engineer, Ohio State Department of Health.

of causes, some of them natural and some of them resulting from the domestic and manufacturing activities of man. Of the tastes and odors having natural origin, the most commonly encountered are those caused by organic matter, by decomposing organic matter and by microscopic organisms.

According to Whipple[3] the first class may have the general description of "vegetable;" the second class variously described as moldy, musty, unpleasant, disagreeable and offensive; and the third class described as tastes and odors of "growth," referring to the activities of microscopic organisms in producing compounds similar to essential oils while living and certain characteristic odors and taste when undergoing disintegration.

It is the writer's desire to focus attention on the first two classes of tastes and odors, those depending on organic matter for their origin, and to consider their occurrence in water supplies taken from rivers and streams. Probably more has been written and said about the origin of tastes and odors in impounded supplies or in natural or artificial lakes, but the importance of their occurrence in rivers and streams must not be overlooked.

Experiences in Ohio will be described most easily by taking as examples three well known municipal water supplies, Cincinnati, Columbus, and Toledo. Cincinnati has the Ohio River as a source of supply with no impounding reservoir, Columbus has the Scioto River with one large impounding reservoir, Toledo uses Maumee River as a source with no impounding reservoir.

Observations at Cincinnati. The Ohio River valley above Cincinnati has a drainage area of 70,322 square miles and an average population density of about 90 persons per square mile. The fall of the stream throughout its whole course varies from 0.1 to 10 feet per mile with an average fall of 0.45 feet per mile. There are thirty-six government dams above Cincinnati built to maintain navigable depth of 9 feet during low water conditions. These dams form pools that exert great influence toward accentuating self-purification of the stream during low flow periods, but which do not affect the character of the water at high stages of the river. Immediately above the Cincinnati water works intake there are no cities or towns contributing any appreciable amount of sewage for approximately 100 miles. Since November, 1907 Cincinnati has been provided with a modern rapid sand filtration plant comprising

[3] Microscopy of Drinking Water, George C. Whipple.

the processes of preliminary sedimentation, coagulation using iron sulphate and lime, filtration, and chlorine disinfection. The daily capacity of the plant is 112,000,000 gallons.

Tastes and odors in Cincinnati water have been observed from time to time and have been attributed to two general sources, (1) the discharge of phenol waste products into Ohio River at points over 100 miles upstream during medium or low flow stages of the river. These occurrences have usually been coincident with local freshets or with artificial waves employed to float coal barges. (2) Sudden rises of Ohio River of considerable magnitude and usually resulting from heavy rains over a large proportion of the watershed.

The conditions first mentioned give rise to tastes popularly known as "medicinal" or "carbolic" and are usually unmistakably identified. The second set of conditions causes a more indefinite taste and odor expressed often as "earthy." An earthy taste or odor may not be particularly objectionable to the water users unless the conditions entering into its cause are extreme and partial decomposition of organic substances present in suspension and solution takes place.

It was observed by the writer, when engaged in detailed study of the Ohio River conditions for the city of Cincinnati in 1912,[4] that sudden and sustained rises of the river resulted in maximum turbidity and maximum oxygen consumed, and both were accompanied by greatly decreased dissolved oxygen conditions of the raw water. Yearly averages show turbidities of Ohio River water in the vicinity of 200 and oxygen consumed of 5 parts per million. On one occasion the writer found in the Ohio River in a sudden summer flood, equal to a rise of 35 feet in the river, a maximum turbidity of 5000 parts per million, a maximum oxygen consumed of 31.5 parts per million and a dissolved oxygen saturation of only 45 per cent. After about a thousand tests for dissolved oxygen had been made and other factors had been studied, it was possible to predict with fair accuracy the dissolved oxygen factor according to the river stage.

It has been observed since that earthy tastes and odors accompanied such rises in the river, particularly when the turbidities and oxygen consumed values approached maximum conditions. That the decrease of the dissolved oxygen constituent is the most important single factor entering into the intensity of these earthy tastes and odors is the writer's opinion. Oxidation of the oxidizable or-

[4] Report on a Plan of Sewerage, City of Cincinnati, 1912–1913. Harrison P. Eddy, Consulting Engineer.

ganic matter in the river will take place and, if no dissolved oxygen is present to oxidize readily such material demanding oxygen, that oxidation must take place at the expense of reducing certain substances. Under such conditions tastes and odors develop that are more markedly objectionable. These represent products of decomposition rather than the purely vegetable tastes and odors. Exact analytical comparisons of tastes and odors with other constituents of raw water such as turbidity, oxygen consumed, albuminoid ammonia, dissolved oxygen, and river stage have not been made as a routine part of filter plant control at Cincinnati, possibly because of the relative infrequency of local complaints regarding tastes and odors.

It is pertinent to note that the studies of color determinations on Ohio River water at Cincinnati have not been of material assistance in indicating the burden of organic matter carried by the raw water. The amount of color found is uniformly low, rarely averaging more than 15 parts per million during any one month. Probably the equalizing effect of the several tributaries making up the Ohio River watershed, accompanied by the adsorption of the color by the suspended clay, is responsible for this fact.

On the accompanying charts are indicated the close relationship of river stage to turbidity and oxygen consumed values, which represent to a fair degree the organic material in suspension and solution that may require oxidation. Figures representing average monthly values for turbidity and oxygen consumed in raw Ohio River water have been plotted against average monthly river stage. Monthly averages for oxygen consumed determinations have also been plotted against monthly averages for turbidities, and show clearly the close relationship of the silt-carrying property of the river water to the oxygen demand made upon it. In addition, there is included in the charts (fig. 4) a summary of dissolved oxygen conditions found to exist according to river stage. Figure 5 shows the average values for the various constituents to be expected for various stages of Ohio River.

Observations at Columbus. The Scioto River from which the city of Columbus procures its water supply has a drainage area above the intake of some 1075 square miles, and an average population on the watershed of 80 persons per square mile. The watershed is generally flat and is largely devoted to agriculture. The river is subject to flashy rises. At a point about 4½ miles above the water

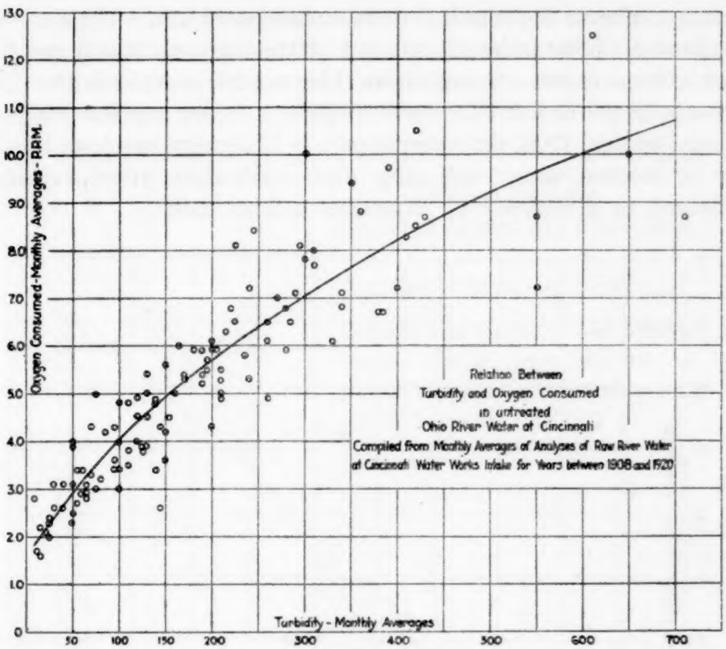
Oxygen Consumed - Monthly Averages - P.P.M.
Turbidity - Monthly Averages
Relation Between
Turbidity and Oxygen Consumed
in untreated
Ohio River Water at Cincinnati
Compiled from Monthly Averages of Analyses of Raw River Water
at Cincinnati Water Works Intake for Years between 1908 and 1920

FIG. 1


River Stage (Feet) - Monthly Averages
Turbidity (PPM.) - Monthly Averages
Relation Between
Turbidity and River Stage
for
Ohio River Water at Cincinnati
Compiled from Monthly Averages of Analyses of
Ohio River Water at Cincinnati Water Works Intake,
excluding 10% of figures representing months of
summer floods of short duration. 1911-1918 inclusive.

FIG. 2

works intake an impounding reservoir has been built. The reservoir is about 5.8 miles in length by some 500 feet average width and 14.5 feet average depth. Storage from this reservoir must be drawn upon to supply the city of Columbus from two to six months per year. Since October, 1908, the water supply of Columbus has been treated by a modern water softening and purification plant, recently enlarged to a capacity of 55,000,000 gallons daily.

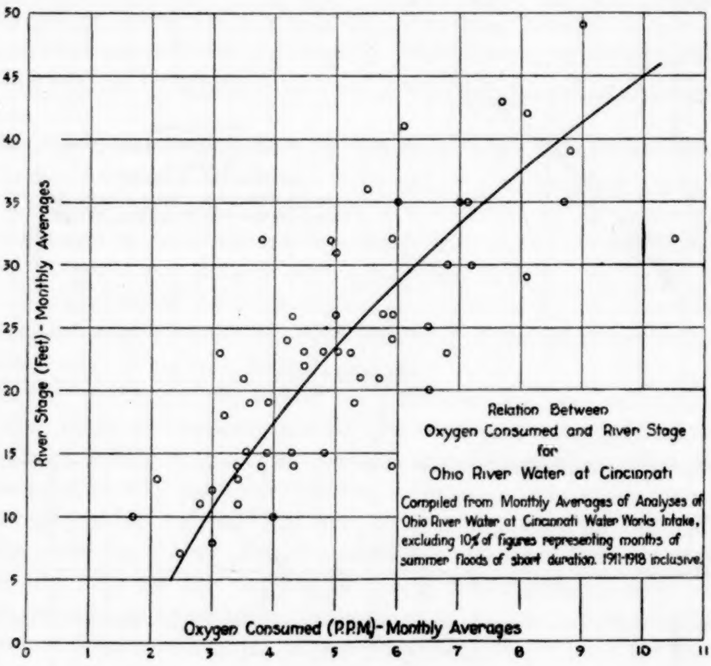

FIG. 3

Tastes and odors in the public water supply of Columbus have been noted. With but few exceptions they have been simultaneous with rises in Scioto River of considerable amount, and resemble the characteristic "earthy" variety previously described. A study of the operating records of the Columbus Plant, compared with local observations by the writer, show that close relationships exist between river stage, turbidity, color and the occurrences of earthy tastes and odors. The color determinations at Columbus furnish a valuable index to the organic matter in solution.

Although tests for dissolved oxygen have been made several times at Columbus in order to learn the relation between oxygen consumed and dissolved oxygen, information has not been of value on account of the aerating effect of the 30-foot fall of the river over

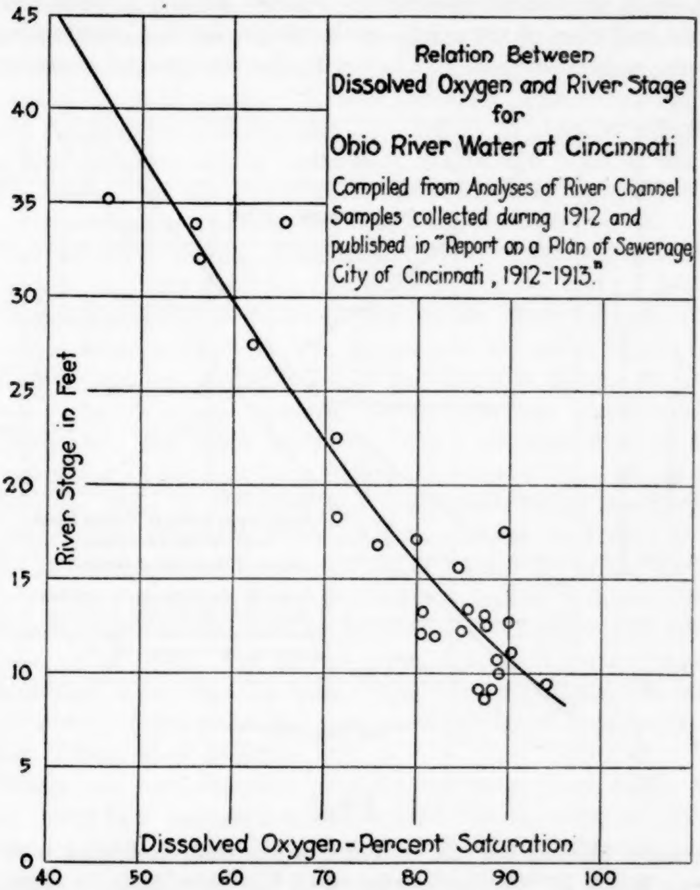

FIG. 4

the storage dam 4.5 miles above the plant. Observations have indicated that the earthy tastes and odors have rarely developed—only twice since the plant was installed in 1908—into disagreeable decomposition tastes noted elsewhere. Plausible explanations of this feature are the oxidation effects of aeration in passing over the

storage dam and down the channel of the river to the intake; the oxygen absorption within the relatively shallow storage reservoir, and the oxygen absorption in the succession of rapids in the Scioto River channel above the reservoir.

A most important observation relative to the appearances of tastes and odors of the mildly earthy nature in the Columbus water supply is the statement of Charles P. Hoover, chemist-in-charge of

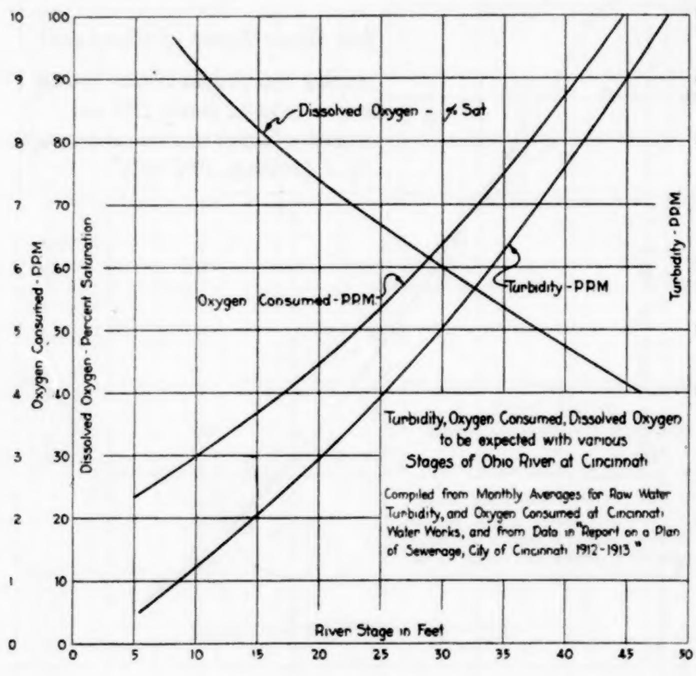

FIG. 5

the water purification and softening works that, beginning with the spring floods of 1922, successful effort has been made to eliminate such tastes and odors by materially increasing the dosage of sulphate of alumina employed for coagulation purposes. Heretofore, during the rise of a flood, it has been easy to accomplish coagulation and, therefore, the water has been treated with only sufficient dosage to effect good precipitation of the suspended matters. It is now the practice to use an additional amount of from two to three grains per gallon of sulphate of alumina, particularly during the earlier

stages of the flood, when the taste and odor producing matters are at a maximum.

The average citizen of Columbus has been more or less educated to recognize the presence of earthy tastes as being associated with Scioto River in flood, so much so that the writer and the chemist-in-charge of the plant have each been greeted with remarks from friends that they knew a flood or a rise in the river must be taking place by reason of the mild "earthy" taste of the water delivered at the tap. Since the practice of increasing the sulphate of alumina treatment has been in effect, during preliminary stages of a flood, it has not been possible for the writer or his acquaintances to detect such river conditions by the taste or odor of the tap water.

Observations at Toledo. The Maumee River from which the city of Toledo takes its water supply, is formed at Ft. Wayne, Indiana by the junction of the St. Joseph and the St. Mary's Rivers. The principal tributaries are the St. Joseph and the Tiffin Rivers from the north and the St. Mary's and the Auglaize Rivers from the south. The Tiffin and Auglaize Rivers enter the Maumee River at Defiance. The whole watershed has a drainage area of 6345 square miles, 74 per cent lying within the State of Ohio, 21 per cent within the State of Michigan and 5 per cent within the State of Indiana. The Maumee River from Ft. Wayne to Toledo is 150 miles in length and has an average fall of 1.1 feet per mile. For the last 60 miles the stream flow is particularly sluggish. Above Toledo the nearest city is Defiance at a distance of 52 miles and with a population of 8876. The largest town, Napoleon, with a population of 4143, is 35 miles upstream. There are important beet sugar industries upon the watershed, but no industries of importance are nearer Toledo than Defiance.

Toledo has been supplied with filtered water since 1910. The plant comprises coagulation and sedimentation, using as coagulants, sulphate of iron and lime, or sulphate of alumina alone, followed by rapid sand filtration and chlorine disinfection. The present capacity of the plant is 56,000,000 gallons daily.

Tastes and odors have been experienced at Toledo on several occasions for periods of long duration. As early as 1912 the city employed consulting engineers to investigate the occurrences and to recommend remedial measures. The first survey of conditions in 1912 indicated that the principal source of trouble was due to coal-tar wastes entering the river below the water works intake and being

carried upstream by wind and shore currents. Proper sewerage improvements eliminated the disturbances noted. Again in 1916 and 1917, pronounced tastes and odors were observed in the public water supply, which persisted over a considerable period during the winter months. The city once more employed consulting engineers,—George W. Fuller, J. W. Ellms, and W. G. Clark—to investigate the causes and to make recommendations for overcoming the disturbances. Opportunity did not prevail for the making of extensive field studies, but the engineers collected sufficient information to enable a preliminary conclusion to be reached. In a conference with the Chief Engineer of the Ohio State Health Department held in February, 1917, the engineers offered the opinion that the tastes and odors might be due to the growth and subsequent decay of vegetation on the river bed and banks, taking place at the time when the river flow was at a low point and icebound for a long period. The city was advised to install aerating devices for the removal of objectionable gaseous constituents and to employ larger amounts of sulphate of alumina in the coagulation process for the removal of dissolved constituents. These recommendations were never followed.

During the period of January to March, 1920 the city experienced the worst tastes and odors in the public supply that have ever been observed. Complaints reached the State Health Department as early as January 21, from the village of Napoleon on the Maumee River, 35 miles above Toledo. On January 23, the city of Defiance, 52 miles above Toledo, entered complaint. Both Napoleon and Defiance have water softening and purification plants treating Maumee River water as a source of supply, although during the time of these complaints the Defiance plant had not yet been completed and placed in operation and raw Maumee River not even chlorinated was being used as a source of supply. On February 24 the city of Toledo formally requested the State Health Department to make an investigation of the tastes and odors. By this time, the people in the cities affected were becoming disturbed over the sanitary quality of the drinking water, in view of the reports in circulation concerning the killing of fish life in the streams and the popular belief that the trouble was caused by a poison emptied into the river upstream by some industrial establishment. The State Fish and Game Department reported that great quantities of fish were being destroyed and was inclined to the belief that a manufacturing plant might be responsible.

Field studies were made by the writer beginning February 26, while the objectionable tastes and odors were at their height. Additional analytical evidence was secured from water samples sent to the State Health Department laboratory for analysis and from records of the Toledo water purification plant. In connection with this survey special analytical work was undertaken by R. W. Furman, superintendent of filtration at Toledo. The sampling points selected were the water works intakes of Toledo, Napoleon, Defiance; the intake of the hydroelectric plant of the Auglaize River Power Company; and the Tiffin River. The Auglaize and Tiffin Rivers enter the Maumee River below Defiance and 15 miles above Napoleon. By the selection of the foregoing minimum number of sampling points an approximation of stream conditions on the watershed was obtained. The field studies included tests for temperature, dissolved oxygen and free CO_2. Laboratory studies included complete sanitary chemical analyses. Of the latter, particular note was taken of the oxygen consumed, the color and the albuminoid ammonia determinations. In all, three field trips were made over the watershed, the second one being March 11 and almost simultaneous with the spring rains and the breaking up of ice in the river.

A study of the conditions noted and the analyses made led to the following summary and conclusions: The stream flow in Maumee River from December to March was extremely low, observed by many of the older inhabitants to be as low as could be remembered. Cold weather was continuous throughout the whole period, resulting in the sluggish Maumee River being icebound with over two feet of ice. At the time of the most severe complaints of tastes and odors the analyses indicated the dissolved oxygen to be at the lowest, 35 per cent saturation, oxygen consumed at its highest, 16.8 parts per million, and color at its highest, 90 parts per million. The dissolved oxygen existed equally low on the tributaries of the Maumee at Defiance, indicating a general watershed condition not due to industrial or other polluting influences, since one tributary, the Tiffin River, drains a territory not contributing domestic sewage or industrial waste. Fish life was being destroyed. At open water points in the vicinity of intakes the affected fish were seen struggling for air. Upon the breakup of the ice and the somewhat increased water flow taking place simultaneously, the dissolved oxygen doubled in amount and the tastes and odors began to disappear. In a few days time thereafter the disturbance was entirely at an end.

The Maumee River conditions of February, 1920 may be described in brief by comparing the sluggish icebound river to a shallow lake becoming stagnant for its entire depth by reason of the ice covering over the many miles of river length. The nature of the odor and taste reported at all points is described by the analysts as being "strong grassy," although popular opinion held the flavor of the tap water to be almost "medicinal." Commenting upon the Toledo observations of 1920, Mr. Ellms is inclined to believe that the breaking down of some of the organic matter in solution may have resulted in complex phenols being formed. That the slight vegetable odor and taste ordinarily present in Maumee River water became disagreeable and even objectionable is due without doubt to the decomposition of the organic matter under conditions practically anaerobic.

Although several beet sugar plants are located on the upper reaches of the Maumee River watershed, which are known to operate in the late fall and winter each year, it was not possible to determine during this investigation what proportion of the organic load carried by the river water was due to wastes from these industries, nor was it possible to determine the proportionate influence of other manufacturing wastes or domestic sewage, as distinguished from organic load contributed from natural sources, as accumulated silt and vegetable matter upon the stream bed.

It would seem that the preliminary opinions reached by the consulting engineers regarding the nature of the trouble in 1916 and 1917 were more than confirmed by the observations of 1920 and that aeration accompanied by generous treatment with sulphate of alumina in the coagulation process would overcome such tastes and odors.

General conclusions. It has been the writer's effort to point out that public water supplies in the Ohio district, derived from surface sources such as rivers and streams, are subject to occurrences of tastes and odors, in spite of the usual purification of these waters effected by modern filtration plants. Such tastes and odors generally may be classified as "earthy" and accompany heavy runoff from the watersheds. Mild earthy odors and tastes are not of particularly great concern to water users (although they are undesirable), except under certain conditions such as great oxygen demand by the organic matter carried in suspension or solution, when these tastes and odors may become objectionable, if the oxidation is unable to take place readily.

Certainly where icebound conditions continue over relatively long periods of time, when sluggish streams carrying considerable organic matter in solution or suspension serve thereby to shut off the oxygen supply available from the air, vegetable or earthy tastes and odors will develop into distinctly objectionable odors and tastes with resultant complaint from water users.

While aeration, accompanied by more complete application of sulphate of alumina as a coagulant in the water purification process, will rid undoubtedly the raw waters of the objectionable constituents, the writer is of the opinion that odors and tastes of purely earthy nature, and perhaps including a limited amount of odors and tastes caused by organic matter undergoing decomposition, may be removed simply by the generous application of sulphate of alumina in the treatment process, using lime or soda-ash, if necessary, to complete the reaction or to correct the condition of the water after sulphate of alumina treatment. Such a procedure should not prove an economic burden upon the purification process, in view of the fact that such tastes and odors take place at the beginning of floods and do not persist over long periods. On the other hand, if more extended and pronounced disturbances, as at Toledo, are to be anticipated with some regularity, provisions in the design and arrangement of the water treatment processes as for aeration should be made. Certainly some additional expense is warranted for the removal of tastes and odors of the class mentioned in this paper, in order to prevent suspicion as to the sanitary quality of the water from entering the minds of the water users.

WATER WORKS ACCOUNTING AT HERKIMER, NEW YORK[1]

By Arthur T. Clark[2]

The numerous, and for the most part misleading, financial reports issued by municipalities owning their own water system and not controlled by a Public Service Commission or similar body, make it very difficult to compare corresponding items of operation. The following water works accounting system, recently installed at Herkimer, New York, and which has been prepared along lines similar to that specified for electric systems by the Public Service Commission, is accordingly presented.

EXPENDITURES

The first step is preparing an invoice for payment. The invoice is approved by the superintendent for goods received, price correct and for payment, and then is turned over to the Accounting Department. At the end of the month, or at such times as it is necessary to voucher the invoices, all of the invoices are vouchered on a form, and distributed to the proper accounts. When the voucher is completed it is numbered and put in the Voucher Record, the amounts appearing in their proper columns, as shown by the Voucher Payable Record. When this operation is completed the vouchers are posted in detail to whatever account they are distributed, and that account may be in the Expense Ledger, the Fixed Capital Ledger or the Material and Supplies Ledger.[3]

In each of the ledgers there is an account to represent the distribution of the classification in the particular class of accounts, as, for instance, the Expense Ledger. The following is a list of the distribution of the operating expenses and there is an account in the Expense Ledger, to represent each account in the classification.

[1] An explanation of the trail of expenditures and receipts through the system of accounting installed in the Water Department of the Municipal Commission of Herkimer, N. Y.

[2] Superintendent, Municipal Commission, Herkimer, N. Y.

[3] Exhibits of these various ledger and record forms may be obtained from the author by request.

Classification of Water Expense Accounts

WATER SUPPLY EXPENSES

Account Number	
301	Works Superintendence
302	Pump Labor
303-A	Boiler Labor
303	Miscellaneous Works Labor
304-A	Lubricants for Power
304	Works Supplies and Expenses
305	Purification Supplies and Expenses
306	Repairs of Works and Station Structures
307	Repairs of Pumps and Accessories
307-A	Repairs of Furnaces, Boilers and Accessories
308	Repairs of Miscellaneous Station Equipment
309	Repairs of Supply Mains and Wells
310	Electric Energy for Pumping
310-A	Fuel for Steam

DISTRIBUTION EXPENSES

311	Water Distribution Superintendence
312	Distribution Supplies and Expenses
313	Water Meter and Installation Work
314	Work on Consumers' Premises
315	Repairs of Water Mains
316	Repairs of Water Services
317	Repairs of Water Meters
318	Repairs of Distribution Tools

COMMERCIAL EXPENSES

319	Commercial Department Accounting—Water
320	Meter Reading—Water
321	Commercial Office Supplies Expenses—Water
322	Advertising—Water

GENERAL EXPENSES

323	Salaries and Expenses of General Officers
324	Salaries of General Office Clerks
325	General Office Supplies and Expenses
326	Miscellaneous General Expenses
327	General Amortization-Water
328	Insurance
329	General Stationery and Printing
330	Store Expense
331	Stable Expense
332	Duplicate Water Charges—Cr.

FIXED CAPITAL LEDGER

The following is a list of the distribution of the Fixed Capital classification and there is an account in the Fixed Capital Ledger, to represent each account in the classification.

Classification of Fixed Capital Accounts

Account Number	
351	Lands and Water Diversion Rights
352	Water Shed Properties
353	Impounding Dams and Reservoirs and Wells
354	Aqueducts and Supply Mains Right of Way
355	Purification System
356	General Equipment
357	Works and Station Structures
358	Pumps and Acessories
359	Acessory Equipment at Works
360	Distribution Storage Reservoirs Lands
361	Distribution Storage Reservoirs and Wells
362	Distribution Mains
363	Distribution Valves, Valve Chambers and Acessories
364	Fire Hydrants and Connections
365	Water Services and Stops
366	Water Meters
367	Water Meter Installation
368	Water Tools and Implements
369	Water Laboratory Equipment
370	Engineering and Superintendence
371	Law Expenditures During Construction
372	Injuries during Construction
373	Taxes during Construction
374	Miscellaneous Construction Expenditures
375	Interest during Construction

MATERIALS AND SUPPLIES LEDGER

The material and supplies are not distributed to any account but to the article itself, such as pipe, valves, general supplies, etc.

CASH RECEIPTS

Cash book record

When a voucher is paid it is entered in its proper column on the credit side of the Cash Book Record. This is the original book of entry where the receipts and expenditures are brought together.

The next step is the reconciliation of the bank balance with the check book. This important matter is always done before the

Cash Book balance is attempted. Then all the vouchers that are paid are checked in their chronological order with the check book stubs and entered on the credit side of the Cash Book. The debit side of the Cash Book is entered from the daily cash receipts, where the distribution of the various accounts is made.

CONSUMERS LEDGER

The Consumers Ledger contains the information for each individual consumer, such as name, address, meter number, kind and style of meter, date turned on and turned off, also the meter readings. The next step is to take off a list on a special Burroughs adding machine of the amount of water consumed and the amount of bill rendered each customer. These totals are later journalized and charged to Accounts Receivable and credited to Operating Revenues Water.

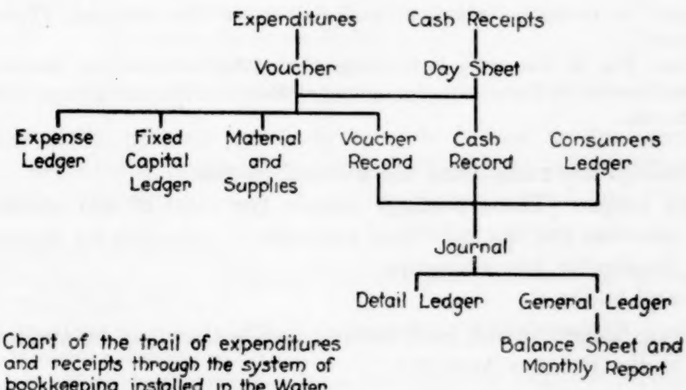

Chart of the trail of expenditures and receipts through the system of bookkeeping installed in the Water Department of the Municipal Commission of Herkimer, New York

JOURNAL

In preparing the journal entries, the entries are made in total to be posted to the control accounts in the General Ledger, as, for instance:

Entire No. 1, an entry from the Voucher Payable Record.
Entry No. 2, the debit side of the Cash Book.
Entry No. 3, the credit side of the Cash Book.

Entry No. 4, the amount of material and supplies used from stock and charged to the various accounts where it is used, and credited to the control account, Material and Supplies.

Entry No. 5, the proportion of insurance applicable to the month is charged to Operating Expenses "Insurance" and credited to the account, Prepaid Insurance.

Entry No. 6, an amount equal to one-twelfth of two percent of the fixed capital installed is set up each month to the account "Operating Expenses General Amortization" and credited to Reserves "Accrued Amortization of Capital Water."

Entry No. 7, the amount of consumers bills rendered customers for the month is set up and charged to Accounts Receivable Water and credited to Operating Revenues Water in its detail.

Entry No. 8, the amount of bills rendered customers for miscellaneous accounts other than water consumed, such as labor, piping, etc., is set up and charged to Accounts Receivable Miscellaneous and credited to whatever account is proper. The detail of the accounts is shown and charged to the individual account in the Detail Ledger.

Entry No. 9, will be the amount of interest for the month that is set up and charged to Interest Deductions and credited to the account "Interest Accrued."

Entry No. 10, this entry is to charge Operating Revenues and credit Accounts Receivable Water with the amount of discounts that are allowed during the month.

Postings are made from the Journal to the:

Detail Ledger: (These postings include the total of the operating revenues and the individual accounts of customers for Accounts Receivable Miscellaneous)

and to the—

Expense Ledger: (which includes any credits that may be applicable to the Expense Account)

and to the—

Fixed Capital Ledger: (for any items that may be applicable to the Fixed Capital Accounts)

and to the—

Material and Supplies Ledger: (the credit for material used from stock, which is credited on the account in the Material & Supplies Ledger, will be posted in detail from the information that goes to make up Entry No. 4)

and all other entries are posted to the General Ledger Accounts, which, in most cases, is the control account of some subsidiary ledger, as will be described later.

GENERAL LEDGER

A list of the General Ledger Accounts is as follows:

ASSETS

Fixed Capital Dec. 31, 1908 Water
Fixed Capital since Dec. 31, 1908 Water
Materials and Supplies
Cash
Accounts Receivable Water
Accounts Receivable Miscellaneous Water
Prepaid Insurance
Interest Deductions Water
Operating Expense Water

LIABILITIES

Funded Debt Water
Interest Accrued
Accrued Amortization of Capital Water
Operating Revenues Water
Other Accounts Payable
Corporate Surplus

After all the postings are made from the Journal to the General Ledger accounts, a trial balance is taken off and the following result should be obtained:

The amount of the account:

"*Fixed Capital December 31, 1908, Water*" will be the total of all the accounts in the Fixed Capital Ledger.

"*Material and Supplies*" will be the balance of the individual article account in the Material and Supplies Ledger.

"*Cash*" will be the amount as shown in the Cash Book Record which reconciles with the bank balance and also balances both sides of the Cash Book Record.

"*Accounts Receivable Water.*" This amount will be the total of the balances of the consumers accounts in the Consumers Ledgers.

"*Accounts Receivable Miscellaneous Waters.*" This amount will be the balances of the accounts in the Detail Ledger under the heading "Accounts Receivable Miscellaneous Water.

"*Prepaid Insurance.*" This amount will be what is shown in the Insurance Premium Register as being prepaid and to be charged later against the Operating Expense Account "*Insurance.*"

"*Interest Deductions.*" This amount will be the amount of interest on the water bonds. No detail is necessary.

"*Operating Expense Account.*" This amount will be the total of each account in the Expense Ledger after all the debits and credits have been made.

"*Funded Debt Water.*" This is the amount of outstanding bonds on the Water Department. No detail is necessary.

"*Interest Accrued.*" This is the amount of matured interest unpaid on the funded debt of the Water Department.

"*Accrued Amortization of Capital Water.*" This is the amount of the reserve that has been set up from time to time to take care of fixed capital that is worn out and retired from service.

"*Operating Revenues Water.*" This amount is the total of the Detail Ledger of the accounts under the caption "*Operating Revenues.*"

"*Other Accounts Payable.*" This is the balance of vouchers unpaid at time when the books are closed for each period.

"*Corporate Surplus.*" This is the amount of net earnings that have accrued from time to time and shown in this account.

The above system was installed under the direction of Mr. Francis O. Wheeler, Public Accountant, of Utica, New York.

THE STANDARDIZATION OF HOSE COUPLINGS[1]

By Norman M. R. Wilson[2]

It is not my intention to deal exhaustively with the subject, but to open the subject for discussion from the viewpoint of those interested in waterworks matters.

The question of standardized hose couplings is constantly being brought to the front with regard to fire departments, but I have seldom heard it mentioned by water works officials.

There is no doubt that it would be well to have all couplings standardized with regard to new waterworks installations, especially in the western Provinces, where there are so many new towns which are and will be going into the question of the installation of waterworks and fire protection.

I have been asked on many occasions why it is that there are so many sizes of couplings. The answer is a simple one. The first protection in case of fire engines was by hand operated appliances made locally, and each maker had his own threads and sizes to work to, usually cutting his own dies. Then came the steam fire engines and the makers of these made their connections to fit the various hose couplings in use. In the same way when waterworks systems were introduced, hydrant couplings were made to conform to the various existing hose couplings.

From a practical point of view, the cost of altering all couplings to conform to a common standard would be so great a tax on the municipalities already equipped that such a thing would be absolutely impossible.

For instance, in the City of Toronto, with 6,833 hydrants, the cost of changing the hydrants alone would be in the neighborhood of $35,000, taking the cost of altering each hydrant at $5. In addition to which, of course, there would be the cost of altering all hose couplings and providing new caps for the hydrants.

The question would also arise as to which department would have to pay for such alteration, for, though the hydrants are under the

[1]Presented before the Canadian Section meeting, May 13, 1922.

[2]Chief Engineer, Water Commissioners, Brantford, Ontario, Canada.

control of the water works department, the chief object in altering would be for fire protection.

The question also arises as to what is the best standard to use? It is generally conceded that the best size of clear opening is the present standard of $2\frac{1}{2}$ inches, which brings the question down to two points, namely, the outside diameter of thread on the male coupling and the number of threads per inch. At present the diameters range from 3 to $3\frac{1}{4}$ inches, and the threads, per inch, from 5 to 8.

A few years ago an investigation of the question was made in the United States. It was found that in the majority of municipalities the outside diameter was about $3\frac{1}{16}$ inches and the threads per inch from 7 to 8. To suit these a standard was adopted having $3\frac{1}{16}$ inches outside diameter and $7\frac{1}{2}$ threads to the inch.

Such a thread in my opinion is not a suitable one. In case of a fire the chief object is speed, and so small a thread is likely to cause delay by cross-threading. This frequently occurred when I was conducting speed tests. The larger the thread the less liability there is to cross-threading, and I have no hesitancy in stating that, in my opinion, the best thread to use is five to the inch. With such a thread there is practically no chance of cross-threading, and it may readily be attached both in the dark and in winter.

Furthermore, it is much more readily cleared of dirt or ice and is much less exposed to breaking or burring than a fine thread.

The simplest and least expensive method for existing municipalities to adopt, in order that they may render assistance to each other in case of necessity, and one which I have induced many municipalities to adopt, is to have each municipality have on hand adapters which will enable them to connect with the surrounding municipalities within a reasonable radius.

TWENTY YEARS OF FILTRATION PRACTICE AT ALBANY[1]

By George E. Willcomb[2]

HISTORICAL

The original sources of supply for the City of Albany were impounding reservoirs situated to the west of the city at such an elevation as to deliver the water by gravity. Most of these sources were spring fed and of deep-seated origin so that the water was highly mineralized and hard. Most of the water sheds were given over to pasturage and much pollution consequently was introduced. In time, with increasing consumption, the supply obtained from these sources became inadequate, and an additional supply from the Hudson River was introduced. The intake, first used in 1873, drew water from the river opposite the heart of the city.

Some sewers entered the river above the intake, but most of them were below it. In times of flood, the water thus obtained was polluted by the sewage of only a few of the city sewers. At low-water stages, however, owing to the tidal currents, the water contained much sewage, carried up stream to the intake. The sewage of the city was present, therefore in considerable amount, in its own water supply.

In addition to the local sources of pollution, the river received the sewage of Troy and the surrounding cities, seven or eight miles above, and the sewage of Schenectady, Utica, Rome and many other places further away. It is estimated that the urban population on the watershed, at the time the pumping-station was built, amounted to 355,000.

Under such conditions the typhoid fever death rate in Albany was excessive, averaging between 70 and 100 per 100,000. In 1885 Prof. W. P. Mason of Troy made a report upon the quality of the water in which he stated, in unmistakable terms, that the water as then used was a source of disease, and should be abandoned at the earliest practicable date.

[1] Presented before the Philadelphia Convention, May 16, 1922.

[2] Sanitary Engineer, Albany, N. Y.

As a result of the agitation for an improved supply, investigations were made of possible sources on the east side of the Hudson, from which the water could be delivered to the city by gravity. Failing to secure the necessary legislation to introduce a gravity supply, and having failed in efforts to develop a deep-well supply to the north of the city, a decision was made in 1896 to investigate methods of purifying the river supply. Accordingly, Mr. Allen Hazen, Consulting Engineer of New York City, who had made extensive studies of European filter plants, was engaged to make the investigation and report to a special water committee.

Just prior to this time Mr. George W. Fuller had made his epochal experiments at Louisville, in which the mechanical or rapid sand process was given a firm status as a method of water purification. As a result, sanitarians became divided into two schools: those favoring the slow sand process, and those advocating the mechanical type. At Albany, the controversy became bitter and both factions held many meetings at which the pros and cons were discussed vigorously. To make matters worse, the City of Rensselaer across the river from Albany, was also considering filtration and had practically decided to install a rapid sand plant. The fact that the rapid process had to employ a chemical in the treatment finally won the day, as it was argued that some of the chemical was bound to find its way into the effluent and thus poison the consumers. In 1897, Mr. Hazen's report was accepted and plans were prepared at once.

It was decided to abandon the river intake opposite the heart of the city and to construct new intakes and plant at the north city line. At this point the river is divided into two channels by Patroon's Island and studies were made to ascertain whether the intake was to be placed in the main river or in the back channel. It was at last decided to locate the intake in the back channel and leave a stub in a junction chamber so that another-intake could be joined on at some future date, should the necessity arise. It might be stated as a matter of interest, that the Hudson River at the point of intake, has a drainage area of 8240 square miles. Of this, 4570 square miles are tributary to the Hudson River above Troy, 3502 are tributary to the Mohawk, and 168 are tributary to the Hudson below the Mohawk. The average annual flow of the streams probably amounts to at least one million gallons per square mile per day, or over 8,000,000,000 gallons per day. It is estimated that the minimum flow is 1,060,000,000 gallons per day. The urban population on the

watershed above the intake was estimated as 479,500 in the year that the plant was built.

Construction was started in April, 1898 and a part of the plant was placed in operation on July 27, 1899. The plant as originally built consisted of a 36 inch cast iron intake main, a low-lift steam operated pumping station, one settling basin, and eight slow sand filter units. The basin was uncovered and constructed of plain concrete slabs with rip-rap masonry at the water line. Its capacity was 16,000,000 gallons and the average lift from the river into the basin was 18 feet. The filters were covered with plain concrete groined arches with brick piers and walls and elliptical concrete arched bottoms. The area of each unit was 0.7 acre. Filter sand was of an effective size of 0.30 mm. and had a depth of four feet, with a four foot head of water on top. Underdrain gravel was approximately 12 inches deep and was divided into 3, 8, and 23 mm. sizes. The main outlet tile drain was 30 inches and the laterals were 6 inch tile. The main collector terminated in a gate valve by which the rate of flow was regulated by adjusting manually, the available head on a 4 inch x 24 inch submerged orifice. Inlet water was automatically controlled by 20 inch float operated balanced valves of the Hamburg type. Great trouble was experienced in adjusting these valves and eventually they were abandoned and the inlets regulated by hand. The clear-well is covered and has a capacity of 600,000 gallons. From the clear-well a 48 inch steel main carries the water to the main high-lift pumping station located at Quackenbush Street. This conduit is 7913 feet long and is laid in the bed of the Erie Canal.

When the plant was first contemplated grave fears were entertained as to the effect of the extreme winters on the efficiency and operation of the slow sand filters. In order to minimize the effect of low temperature as much as possible, a backfill of two feet of clay and loam was placed on top of the beds; but twenty-three years of operating experience has proved that the frost penetrates through this backfill and filter roof, so that, if the length of runs is prolonged unduly in winter, the result is apt to be the forming of a layer of ice on the water surface of the beds, that ranges from four to six inches in depth. This coating of ice seriously interferes with the operation of the filters, in that it must all be floated off before the filter can be drained for scraping. Several winters have occurred in which the runs have been so unduly prolonged as to practically freeze up the plant so that it could not be efficiently operated.

The cost of the entire project as constructed was approximately $500,000 and its normal capacity 14.7 million gallons. As the normal consumption at the time the plant was built was in the neighborhood of 19 million gallons daily, it will thus be seen that there remained 4.3 million gallons daily to be derived from the old gravity sources. This was expected to be the case, however, for when the project was originally planned it was ascertained that little of the typhoid was derived from the gravity supply and that practically all cases came from drinking river water. It was planned to correct this by installing filters.

PRESENT PHYSICAL CONDITION OF PLANT

Today, after nearly 23 years use, the physical condition of the slow sand plant is excellent and stands as a monument to its designer. Aside from a few contraction cracks about the manholes and arch crowns, the concrete is intact, and there have been no failures of any kind. During the summer of 1921 it was decided to add new sand to the beds, as in many cases the depth of sand had been reduced to 24 inches. This new sand was dredged from the river and cost $1.95 per cubic yard in place in the beds.

A brief description of the present condition of the 48 inch steel filtered water conduit follows, as it is thought that such data will interest engineers, who may be weighing the qualities of cast iron pipe and steel in order to reach a decision as to which type of pipe is the more feasible for a particular project. As was described above, this conduit lies in the bed of the polluted Erie Canal for most of its length, and as it is normally not under pressure, there was some fear that it might be so corroded in places as to allow the canal water to enter it and contaminate the filtered supply.

The pipe is made of mild open-hearth steel plates 5/16 inch thick. Practically throughout its entire length under the canal, the pipe is covered with a concrete shell varying in thickness on the bottom of 9 inches, to 6 inches on top. This was done to support the steel in deep cuts and to prevent the pipe from floating should it be emptied any time for inspection. It is clear, therefore, that; even though all the steel pipe should be rusted away, there would remain a concrete pipe, that, while not water tight in the strictest sense of the word, would serve its function to all intents and purposes. Where the conduit leaves the filter plant there was left a short stretch uncovered by concrete that gradually became a source of conjecture to

those responsible for the safe passage of the water to the city. In 1910 this portion was inspected by the writer who found that aside from some marked tuberculation, the pipe was in very fair condition. In the summer of 1921 certain portions of the outside of this pipe were bared and it was discovered that the top portion was badly corroded. Patches as large as a dollar were exposed with holes of $\frac{1}{8}$ inch diameter in their centres. Plans accordingly were made to surround this section of the pipe with a nine inch shell of concrete and the work was actually carried out in the fall of 1921. When the entire length of the portion to be repaired was finally exposed, seventy-eight holes were found in the top portion of the pipe through which water was leaking. The best reason advanced for this phenomenon was that the trench was excavated in shale and the sub-surface water in percolating through this shale had picked up enough sulphur compounds, which, upon odixation, finally formed sulphuric acid the active agent in the corrosion.

IMPROVEMENTS AND EXTENSIONS

Although the original plant was designed to produce an average daily output of approximately 14.7 million gallons, it will be noted from the table of production and cost summary that follows, that this yield was seldom attained. The chief difficulty seemed to lie in the fact that, owing to the clogging of the sand and the consequent penetration into the lower strata of the filtering medium of organic growths, the runs gradually became shortened to such an extent as to necessitate taking off two filters at a time for cleaning. This sub-surface clogging will be taken up separately in a later portion of this paper.

After a time pressure was brought to bear, by those consumers supplied with water from gravity sources, to abandon all of the gravity sources and to place the entire city on filtered water. This feeling was accentuated by the yearly troubles brought about by growths of micro-organisms in the gravity supplies, imparting disagreeable taste and odor to the water. Another factor that gave impetus to this movement was that, on occasions, a bad tasting water was obtained from the filters that suggested coal tar gas or oil. Experiments were made on samples collected from the main river and back channel and it was found that those from the main river had less pronounced odor and taste than those collected from the back channel.

In 1905 plans were gotten out for a new intake situated in the main channel of the river and an appropriation was also obtained for conducting experiments to ascertain how the yield of the filters might be best augmented. At that time experiments had been carried on at Philadelphia with a process of preliminary filtration, in which the settled water was given a filter treatment at a high rate without the use of a coagulant. By this preliminary or scrubbing process it was found that the final slow sand treatment could be carried on at twice the customary rate, or at the rate of 6 million gallons per acre per day.

This process was tried experimentally at Albany for a year in small units of from 8 to 16 square foot areas. As a result of these experiments it was learned that the effluent of a preliminary filter operating at a rate of 75 million gallons per acre per day could be successfully passed onto a slow sand unit, which could be made to operate at an average rate of 6 million gallons per acre per day. It is seen that such a plan would mean a practical doubling of the capacities of the original slow sand units at a great saving of cost. It was estimated that the total cost of the preliminary filters, including intake, pumps, filters, and equipment, would cost in the neighborhood of $300,000; while to build 8 additional slow sand units would cost nearly $600,000, so that it is apparent that the construction of preliminary filters was by far the more economical proposition.

As a result of these experiments plans were prepared, and the construction of the plant was finished October 29, 1908. The actual cost of the entire improvements was $288,700. Assuming a capacity of 40 million gallons per day for this plant, it is seen that the unit cost was slightly over $7000 per million gallons capacity. This characterizes this plant as being one of the cheapest plants that had been constructed. As built, it consisted of 16 units, each having 810 square feet of filtering surface. The beds were divided into halves by a central wash gullet and the gutters were spaced 7.5 feet apart. The sand was 30 inches in depth and had an effective size of 1 mm. when put in. The gravel was 18 inches deep and ranged in size from 3 inch to $\frac{1}{16}$ inch. The entire underdrain lateral system was built of concrete, the small ducts being trapezoidal in section. The sand valves consisted of seamless drawn tubing, $\frac{1}{2}$ inch in diameter and 5 inches long. The holes, eight in number, were located about the periphery and were approximately $\frac{1}{8}$ inch in diameter. When the valves were connected with the underdrain ducts and the

concrete floor poured, it left a flat deck with the perforated ends of the ferrules projecting up two inches above the floor and 9 inches on center. It will be readily seen that this arrangement is most simple and practically indestructible as there is nothing but concrete and brass and the holes are large enough to pass any small sand grains that might penetrate the gravel layer. The plant has been in operation for 14 years and practically nothing has been done to the underdrains or filters except to pack valves and align the wash gutters.

It may be noted from the operation data of the slow sand filters, that for nine years following the installation of the preliminary filters, the average rates of the former were materially increased and for a few years the beds were actually run at a six million gallon rate; but gradually, as the organic matter passing the preliminary beds penetrated below the surface layer of the slow sand units, the average rates began to fall off, until they were finally about the same as before the preliminary filters were introduced. The trouble was due to the fact that the experiments were not carried on for a sufficient time to demonstrate the passage of the fine organic matter through the preliminary filters. This passage of organic matter is a function of time as is demonstrated by the fact that it was two years before the preliminary units showed signs of faulty washing by the gradual appearance of mud-balls in the sand. After this it became necessary to eject all sand from the preliminaries each year, and pass it back into the beds again through the Nichols Separator, in order to free the sand of silt and organic growths.

It will be noted from Table 1, for the preliminary filters, that the reduction in bacteria and turbidity was 76 and 80 per cent respectively, with the filters operating at an average rate of 77.5 million gallons per acre per day. The average wash water used was 3.5 per cent and the rise was at a rate of 1.3 feet per minute. The average length of run at the above average rate was 37 hours. Under the special heading of cleanliness of sand, found in another portion of this paper, will be found data concerning the condition of the sand in these filters. The preliminary filters were washed at first arbitrarily at a seven foot loss of head, which resulted in their operating under a maximum of a 4.5 foot negative head. At times, when they were receiving coagulated water, it had been the custom to wash them when the loss of head totaled four feet. This was necessary on account of the coarse sand used, which caused the passage through the bed of hydrate of alumina at greater losses of head. It is rather

surprising that filters using such coarse sand are able to deliver an effluent as free from hydrate as these do under the conditions imposed.

In 1914, a plant was erected for handling alum to be applied to the water as it enters the basin. This plant was designed to handle the alum hydraulically and has been in successful operation ever since. It was thought that, by coagulating the water at certain times of the year, better results would be obtained in the operation of both sets of filters. It became the practice to coagulate the water at times of high turbidity and at such times as the organic matter in the river was above normal. As a result of this procedure a better wash was obtained in the preliminary units and the length of run of the slow sand beds was materially increased.

TABLE 1

Preliminary filters; miscellaneous data

Year	Gelatin count—effluent			Per cent reduction gelatin count	Agar count	Turbidity	Color	Average per cent wash	Average rate of filtration	Average length of run hours	Per cent reduction turbidity	Remarks
	Maximum	Minimum	Average									
1909	91,200	80	11,450	84.7		10						Preliminary filters
1910	139,000	140	6,750	90.0		3	30	3.2			73.2	placed in opera-
1911	85,000	110	7,500	80.7		5	30	4.1		35	71.9	tion Oct. 29, 1908
1912	122,000	475	16,100	71.1		12	33	3.8	81.0	32	55.3	chlorination be-
1913	96,000	175	11,150	80.5		17	26	4.8	79.4	32	63.4	gan July 26, 1909
1914	152,000	175	14,775	79.7		8	24	3.6	84.5	40	77.6	Coagulation started
1915	38,000	120	3,800	73.6	110	2	19	3.8	81.0	30	82.9	
1916	76,000	65	10,725	73.9	130	3	23	4.8	81.2	30	7.78	
1917	61,600	300	10,500	78.5	170	3	32	3.3	79.6	32	7.77	
1918	28,000	200	4,000	67.9	70	0+	22	3.0	80.0	32	92.6	
1919	11,650	350	2,100	77.5	80	0+	19	2.2	72.1	45	97.5	
1920	41,000	500	5,400	69.7	475	1	27	2.5	73.2	40	91.3	
1921	12,000	350	3,500	63.6	500	1	24	2.0	73.9	55	92.4	
Ave.			8,300	76.0	220	5	26	3.5	77.5	37	80.0	

During January 1914, owing to a combination of circumstances, the city was faced by a water famine. Rensselaer Lake, the largest gravity supply had already been so depleted as to offer no assistance. The penetration of organic matter into the lower sand strata had

become so great that the length of run was reduced to about 14 days. To make matters worse the temperature fell to below zero, resulting in an excessive demand on the part of the consumers for water to be run to waste in order to prevent the freezing of plumbing fixtures. A hasty decision was made to cut holes through the walls of two of the slow sand filters so that water from the tops of these filters might be introduced directly into the clear well and augment the supply. Two sixteen inch valves were inserted in these holes and under the head available, these valves were able to deliver a maximum of about 12 million gallons per day into the clear well. It will be recollected that the water introduced in this way had already passed through the preliminary filters, but had a high bacterial count and had many acid forming bacteria and typical coli. This mixture of filtered and partially filtered water was passed through a weir where sufficient chlorine was added to produce a potable supply for the city. The introduction of this by-passed water into the clear well was one of the most important decisions that had ever been made in connection with the management of the Albany works. It meant practically that the main dependence from that time on was to be placed on the preliminary filters rather than on the slow sand. As a matter of fact, ever since then, it has been the custom to get as much water as possible from the slow sand units and then make up the deficit from water by-passed from the preliminary plant. During the early portion of this by-passing resort was had to chlorine alone to obtain a potable water; but as the amount of water by-passed became greater from year to year, and the organic matter in the combined effluents increased in amount, it became customary to always coagulate the basin water when by-passing was used.

This practice could only lead to one result, the ultimate abandonment of the slow sand plant as the principal source of filtered supply. Each year more and more water was taken from the preliminary units direct, until it was quite common to by-pass as much as 60 per cent of the out-put of the plant around the slow sand units. Another factor that favored this procedure was that the coagulation eliminated most of the color that had always been present in the slow sand effluent. In the summer months when the river was low, a great deal of swamp water from the Adirondack watersheds was introduced into the river in an undiluted state. This brought the color of the river water up to 60 parts per million and, at the best, the slow sand units could only reduce this color to about 30. With

coagulated water, the color could be brought down to below 10 parts per million, a fact that was readily appreciated by the consumers. During the year 1921, coagulation was employed for 232 days. This practically means that the plant was operating on a mechanical filter basis for nearly 65 per cent of the year. (Table 2.)

On April 12, 1920, the State Department of Health made a report, after an extended investigation, in which the absolute abandonment of the slow sand plant was advocated. In this report it was recommended to divide the basin into two portions, build a new chemical head-house, replace the coarse sand in the preliminary filters with a suitable sand of lower effective size, and make use of the slow sand units for a clear water revervoir. In the next report of the Commissioner of Public Works these changes were endorsed, though modified somewhat. The Commissioner emphasized the unbusinesslike procedure of paying for a coagulant and at the same time maintaining a full crew of laborers to operate the slow sand filters, when for a greater portion of the year they were operating below their normal rate, without any effort being made to keep them up to capacity.

TABLE 2

Coagulation data; sulphate of alumina used

YEAR	NUMBER OF DAYS ALUM USED	GRAINS PER GALLON ADDED			PER CENT REDUCTION IN GEL-COUNT DUE TO ALUM	COST		AVERAGE ALKALINITY		AVERAGE HARDNESS	
								Parts per million			
		Maximum	Minimum	Average		Total	Cost per million gallons to treat	Raw	Treated	Raw	Treated
1914	110	4.24	1.42	2.56	74.3			67	54	73	78
1915	259	3.55	1.20	2.05	79.1	16,454	2.89	69	57	75	80
1916	67	3.08	1.29	2.17	83.5	4,018	2.76	68	66	66	66
1917	34	3.00	1.10	1.42	75.3	2,625	4.03	78	75	73	78
1918	182	3.00	1.10	1.80				66	56	72	75
1919	183	3.00	1.60	1.90	67.4	20,522	5.63	52	53	72	75
1920	49	2.60	1.10	1.50	56.2	4,132	4.01	50	50	75	75
1921	232	2.37	1.39	1.86	66.6	27,792	6.11	46	38	73	76
Average.......				1.91	71.7		4.24	62	56	73	75

SAND HANDLING AND CLEANLINESS OF SAND

From the time the slow sand filters were started up to 1905, the scraped sand was wheeled out of the beds in wheel-barrows and de-

posited in piles in the court-yard, to be washed by means of a stationary sand washer the next day, and then wheeled back into the bed again. This procedure was expensive and laborious and required handling of the sand many times. In 1905 a portable ejector was perfected by means of which a hopper could be carried into a bed and the sand ejected out to the storage pile. As only 50 pounds water pressure were available, only one ejector could be operated at a time; but, a few years later, a special pump was installed furnishing water under 100 pounds pressure so that two ejectors could be operated.

The next important step in the evolution of sand washing occurred in 1908 when the Nichols Sand Separators were introduced. By means of this process, the sand could be ejected to these separators located within the bed itself; and the sand cleaned and deposited back in place, in one operation. While this method was used at times, the standard has been to eject all of the scrapings out to a storage bin in the rear of the beds and to replace all sand in the beds at one time during the summer months.

At different times various other methods of washing sand were given a tryout. The so called Brooklyn method of introducing a surface wash by applying water to the surface of the bed and at the same time raking the sand was tried with little success. Likewise, the method of raking the "schmutzdecke" at the end of a run and then starting the filter off again, failed to give results commensurate with the additional labor involved.

It is seen, therefore, that for fourteen years the method of handling sand has been the same. This fact does not speak well for the progressiveness in the art of slow sand filter operation. Indeed it is this lack of progress in the means of filter maintenance that has caused the local plant to become less effective. Cleaning a slow sand filter is at best a most cumbersome and laborious process, and when a bed becomes congested with sub-surface clogging, entailing the removal and cleaning of a foot to a foot and a half of the top sand, the job is indeed a formidable one. It is true that the phenomenon of sub-surface clogging has been experienced perhaps more severely at Albany than elsewhere. It is likewise true that the condition of the raw water has a great deal to do with the performance of any particular plant, but the fact remains that the organic penetration into the lower strata of the slow sand units has been a constant source of disturbance at Albany and has resulted in a serious lessening of their efficiency and dependability.

In order to ascertain just what the condition of the sand was in the lower portion of the beds, surveys were made by collecting samples at all portions of the sand surface and at different depths. These samples were collected by means of a special sand auger or by means of a 3 inch corrugated steel conductor pipe. This latter means was most efficacious, as the tube could be driven to any predetermined depth and the core of sand removed gave an ideal sample upon which to base an opinion of the condition of the sand at that particular point.

In order to ascertain just what the condition of the sand was, special chemical methods were devised to determine the amounts of nitrogenous and carbonaceous organic matter retained in the sand, also the turbidity as indicated by the turbidimeter. In the first place the percentage moisture contained in the sand was determined and then an amount of sand just equivalent to 100 grams of dry sand was added to 100 c.c. of distilled water and agitated under standard conditions in a sand shaking engine for one minute. It will be noted that the conditions of the preparation of the samples were purely arbitrary, for, if the time of shaking was varied or the amount of distilled water was changed, the results would vary. As a comparison of results was always looked for, the standard method as used gave concordant results. After shaking, the sand is allowed to settle and the supernatant liquid containing the organic floc in suspension is immediately decanted, and aliquot amounts taken for the determinations. On these decanted samples the following determinations were made: organic nitrogen, oxygen consumed, and the turbidity of the sample as indicated by a candle turbidimeter. The results obtained were expressed as parts per 10,000 grams of dried sand.

This method was especially valuable in locating the penetration of organic matter in the slow sand units, establishing the efficiency of a Nichols Separator, or the efficiency of wash of the preliminary filters.

Following is given the results of a survey of the slow sand units made in 1912, before and after replacing fresh sand upon the filters. In this instance, before any sand was added, the top ten inches of the old sand was ejected through a Nichols Separator and back onto the bed again, then ten inches of fresh sand was ejected from the storage piles in the rear of the filters back into the beds, thus making the top 20 inches a layer of clean sand.

	RESULTS IN PARTS PER 10,000 GRAMS OF DRY SAND		
	Turbidity	Organic nitrogen	Oxygen consumed
Slow sand No.1			
Top 10 inches before cleaning	1,000	2.0	11.3
Section 10 to 20 inches depth	950	1.75	10.1
Section 20 to 30 inches depth	800	1.50	10.0
After washing			
Total 30 inches section	650	1.00	7.5
Slow sand No. 2			
Top 10 inches before cleaning	1,700	2.0	15.0
Section 10 to 20 inches depth	1,200	1.55	14.0
Section 20 to 30 inches depth	900	1.10	9.5
After washing			
Total 30 inches section	850	0.90	7.6
Slow sand No. 3			
Top 10 inches before cleaning	2,000	1.76	14.0
Section 10 to 20 inches depth	1,500	1.36	12.2
Section 20 to 30 inches depth	1,000	1.28	11.6
After washing			
Total 30 inches section	700	1.50	10.5
Slow sand No. 4			
Top 10 inches before cleaning	1,200	1.80	9.0
Section 10 to 20 inches depth	900	1.70	6.8
Section 20 to 30 inches depth	650	1.44	5.5
After washing			
Total 30 inches section	650	1.20	4.5
Slow sand No. 5			
Top 10 inches before cleaning	1,800	2.50	14.0
Section 10 to 20 inches depth	1,500	1.80	8.8
Section 20 to 30 inches depth	1,100	1.60	7.4
After washing			
Total 30 inches section	800	1.20	6.5
Slow sand No. 7			
Top 10 inches before cleaning	1,500	1.80	15.5
Section 10 to 20 inches depth	800	1.60	12.4
Section 20 to 30 inches depth	700	1.55	11.2
After cleaning			
Total 30 inches section	650	1.00	9.5

The following data are representative of the conditions in a typical slow sand unit before and after renovating and replacing the sand in a bed.

	Parts per 10,000 grams sand		
	Turbidity	Organic nitrogen	Oxygen consumed
Before replacing			
Average section 0 to 10 inches	900	1.70	13.0
Average section 10 to 20 inches	875	1.24	12.2
Average section 20 to 30 inches	870	1.22	11.3
After cleaning and replacing			
Average section (entire bed) 0 to 30 inches	675	1.53	10.1

It will be noted from the above data that the ejection wash appears to be more efficient in the removal of the constituents measured by the turbidity than it does in the removal of organic matter, as might be expected. On examining the sand grains through a microscope, it is seen that the grains are encased in a film of amorphous matter and fungi, that would appear very difficult to remove by any washing process unless accompanied by a vigorous agitation. It is evident that the ejection process of washing fails to accomplish this.

The following data serve to indicate the conditions within the sand strata in winter time, the samples having been collected in the month of December. The samples were collected at different parts of a slow sand unit and should be thoroughly representative. From a study of the various constituents it is interesting to note how uniform the filtering medium appears to be.

Section	Effective size	Uniformity coefficient	Per cent moisture	Parts per 10,000		
				Turbidity	Organic nitrogen	Oxygen consumed
Schmutz.	0.30	2.33	9.0	3,500	1.72	14.8
Schmutz.	0.31	2.33	14.0	3,600	1.80	16.1
0 to 36 inches	0.33	2.75	14.0	1,200	1.20	5.1
0 to 36 inches	0.29	2.58	16.0	1,400	0.80	8.5
0 to 36 inches	0.32	2.50	17.0	1,500	0.80	8.3
0 to 36 inches	0.30	2.66	15.0	1,400	0.80	9.3
0 to 36 inches	0.30	2.50	16.0	1,400	0.80	7.8
0 to 36 inches	0.33	3.63	16.0	1,500	0.80	9.4
0 to 36 inches	0.30	2.66	13.0	1,500	0.75	7.4
0 to 36 inches	0.30	2.66	9.0	1,300	0.78	8.0
0 to 36 inches	0.30	2.40	13.0	1,100	0.82	8.0
0 to 36 inches	0.30	2.33	13.0	1,400	0.80	6.9

The figures below show the efficiency of wash as developed in one of the mechanical scrubbing units or so-called preliminary filters. The samples before the wash were obtained from four points in the bed at 2, 8 and 20 inch depths, respectively. Length of wash 6 minutes, rise 1.3 feet.

Before washing

SECTION	EFFECTIVE SIZE	UNIFORMITY COEFFICIENT	TURBIDITY	ORGANIC NITROGEN	OXYGEN CONSUMED
A—0 to 2 inches	0.45	1.78	2,200	1.52	19.5
B—0 to 2 inches	0.42	1.57	2,000	1.76	19.9
C—0 to 2 inches	0.44	1.70	1,600	2.08	20.5
D—0 to 2 inches	0.46	1.91	2,300	1.84	20.1
Average 0 to 2 inches	0.44	1.74	2,025	1.80	20.0
A—2 to 10 inches	0.48	2.25	850	1.36	17.2
B—2 to 10 inches	0.57	2.00	650	1.20	15.0
C—2 to 10 inches	0.58	1.84	800	1.04	15.1
D—2 to 10 inches	0.74	1.49	900	1.04	14.8
Average 2 to 10 inches	0.59	1.90	800	1.16	15.5
A—10 to 30 inches	0.54	2.04	850	0.96	16.2
B—10 to 30 inches	0.58	2.00	800	1.04	14.4
C—10 to 30 inches	0.52	2.19	750	1.04	14.6
D—10 to 30 inches	0.55	2.19	900	1.44	14.2
Average 10 to 30 inches	0.55	2.11	825	1.12	14.9

After washing

SECTION	TURBIDITY	ORGANIC NITROGEN	OXYGEN CONSUMED
Average 0 to 2 inches	1100	1.12	15.6
Average 2 to 10 inches	875	0.88	13.5
Average 10 to 30 inches	750	0.90	13.0

Efficiency based on the percentage reduction in the turbidity, organic nitrogen, and oxygen consumed factors in the different sections.

SECTION	TURBIDITY	ORGANIC NITROGEN	OXYGEN CONSUMED
	per cent	*per cent*	*per cent*
0 to 2 inches	46.3	37.8	22.0
2 to 10 inches		24.1	1.5
10 to 30 inches	11.8	19.6	1.2

Interesting points of the above data are the evidences of sand stratification as indicated by the effective size of the sand grains at different depths, the greater efficiency of the wash in the top two inches of the filter, and the small efficiency attained in removing carbonaceous organic matter from the lower strata of the bed, as indicated by the oxygen consumed factors.

CHLORINATION

Disinfection by means of hypochlorite of calcium was begun at Albany on July 26, 1909. It is probable that this was one of the first cases where a large purification works resorted to a chemical disinfectant to improve the quality of its effluent. Without doubt this step was one of the most important decisions that had been made since the works were first started and was destined to effect far reaching changes in the manner of operating purification plants in general. Up to this time the main factor that determined the efficiency of filtration was good plant design and intelligent supervision. In other words, if great care were not exercised in the design and operation of a plant, the effluent at times was apt to be of poor quality and there was absolutely nothing that could be done to overcome this condition. It was natural then that everything was done in designing a plant to assure ease of operation, adequate plant capacity so that the filters would not have to operate beyond their rated capacities, and to render the plant as fool-proof as possible. As a result of this, much experimentation was always employed before any large project was designed to make sure that the plant would conform to the local conditions imposed by the quality of the raw water. Plant design under such conditions improved steadily and it may be said that the greatest progress in the details of filter construction was made during the period between 1890 and 1910. Since that time many new plants have been built embodying many unique features in their detail, but there have been few radical changes in the principles involved. Steadily but surely, less and less attention has been paid to the mode of operation of plants, and, where the consumption has increased, the filter rates have been increased in proportion, the main dependence being placed upon the disinfection process to overcome the poorer quality of the resulting filter effluents. In certain instances this procedure has been employed to an extreme limit, resulting in an effluent so poor, that if anything should happen to interfere with the running of the chlorine apparatus, disastrous results would be sure to ensue.

The foregoing remarks apply, in some respects, to the conditions that have been brought about at Albany during the past ten years. In the beginning, the introduction of chlorine was undoubtedly of great sanitary significance in that its application at certain times of the year, when temperature conditions rendered the filtration process most inefficient, brought down the bacterial counts in the effluent to a state approaching normal. It was a common occurrence in the winter months, when contraction occurred in the filtering medium, to have bacterial counts in the effluent of the slow sand filters as high as 8000 on gelatin, with corresponding proportions of coli and acid formers. At such times the only recourse was either to shut certain filters off or to reduce the rate of filtration to a minimum. This practice, of course, could not be resorted to for a prolonged period, as there would result an insufficient amount to meet the consumption. With the advent of chlorination, however, such rough spots could be eliminated, and the final treated effluent was always of uniform quality. Such an agency was undoubtedly of great assistance to the process, but, as time went on, and the slow sand filters gradually became clogged in their lower strata, necessitating the by-passing of water from the preliminary units, the increasing number of bacteria in the final effluent was kept down to within safe limits by applying an adequate amount of chlorine to the combined yield from the works. In other words, the easiest and cheapest way out of an increasing difficulty was employed. Instead of constantly maintaining the slow sand units in a state of highest efficiency, or increasing the number of units, as would have been done had there been no disinfection to fall back upon, resort was had to chemically treating the water, which was satisfactory enough as long as it was added in sufficient amount, and there was no interruption in its application; but which allowed an element of chance to be introduced, which at a time of high bacterial content in the filter effluent was an unpleasant thing to contemplate.

In the early stages of the chlorination process as employed at Albany, the hypochlorite solution was added, by means of a crude device, to the water entering the settling basin. At that time no alum was being used and the chlorination of the basin water effected a large reduction in the bacterial count at this stage of the process. It was thought that better results might be obtained if the chlorine were added to the preliminary filter effluent, so the next step was to move the plant so that this could be accomplished. After treating

the preliminary effluent for nearly one year, it was decided that better results could be obtained by treating all of the water at one point in the clear well, just before the water entered the tunnel leading to the city.

In the fall of 1911 a new plant was built for the handling of hypochlorite. The buildings were detached and so designed that the drums of bleach could be opened on the roof and poured into a mixing tank within the building. This meant that the man opening the drum could stand in such a position that the wind would carry the powder away from him and thus a very annoying feature of the process was removed. The mixer was well provided with agitators and the chlorine of an 800 lb. cask of bleach could be whipped out into solution in eight hours. The dose for the day was then computed and the solution was discharged into special settling tanks, where the lime was allowed to settle out for 24 hours. A floating orifice on the surface of the clear solution carried the clarified liquor to a measuring device, where the dosage was regulated. This device gave good service until August 1916 when the price of bleach began to soar on account of speculation brought about by war conditions. As the price of liquid chlorine was much more stable, it was decided to substitute this for bleach and the chlorine control apparatus was installed during August 1916. The hypochlorite plant was kept intact so that it might be available should an emergency occur. As a matter of fact, when the price of bleach was lower than that of liquid chlorine, the former had been substituted on several occasions.

The main factor affecting the reaction of chlorine at Albany has been the amount of organic matter in the applied water. During the later summer months when the river was at a low stage and the organic matter in the raw water was very high in consequence, the tendency was for the chlorine to become absorbed and rendered inert, necessitating larger amounts to accomplish the work. At such times a peculiar taste in the water was apparent that somewhat resembled the taste of phenol and was undoubtedly caused by the formation of oxychlorides. The taste at times was so pronounced as to cause complaint by many consumers. At such times it has always been the practice to start up the coagulation process and take out as much as possible of the organic matter in the basin, before the chlorine was added to the final effluent.

A study of the data for typical months of high and low organic content waters clearly demonstrates the retardation brought about

by the absorption of the chlorine by the organic matter. It is the organic matter measured in terms of oxygen consumed, or in other words, the carbonaceous organic matter, that interferes with the action of the chlorine. For the months of March and August, 1916, under comparison, the albuminoid ammonia factors were practically the same, but in August the oxygen consumed factor was 3.5 times greater. In March it required only 0.44 parts per million of chlorine to reduce the maximum gelatin count below 50 per cc., while in August a dose of 0.94 part per million was just able to reduce a count of 200 to just below 50. In each month the coli were eliminated from all of the 1 cc. samples of treated water, but it required

TABLE 3

Disinfection data; hypochlorite and liquid chlorine used

YEAR	CHLORINE ADDED. P.P.M.			PER CENT REDUCTION IN GEL-COUNT DUE TO CHLORINE	COST		EXCESS CHLORINE CARRIED IN TREATED WATER
	Maximum	Minimum	Average		Total cost	Cost per million gallons to treat	*p.p.m.*
1913	1.03	0.11	0.49	91.4			0.0
1914	0.90	0.17	0.43	98.1			0.0
1915	0.90	0.17	0.43	90.0			0.0
1916	1.12	0.15	0.44	88.0			0.0
1917	0.77	0.11	0.59	90.8			0.0
1918	1.40	0.18	0.73	91.0			0.0
1919	1.47	0.18	0.67	92.0			0.05
1920	1.33	0.13	0.59	80.5	3,687	0.51	0.09
1921	1.00	0.10	0.40	86.0	1,994	0.28	0.15
Average.....			0.53	89.8			

22 per cent more chlorine in August to bring this about, while there were over 400 per cent more coli in the applied water during March, and 100 per cent more water was by-passed around the slow sand filters.

It became apparent gradually that the method of applying chlorine only in sufficient amount to bring the bacterial counts down below a definite number, and to eliminate all coli from 10 cc. samples, was not enough, for the typhoid cases were still too numerous. In 1919 the procedure was adopted of always adding sufficient chlorine to maintain an excess of at least 0.05 part per million after the chlorine had acted for one minute on the water in a baffled reaction chamber.

In 1920 the excess maintained was increased to 0.10 part per million, and again in 1921 it was still further increased to 0.15 p.p.m. Since 1919 there has been a marked diminution in the number of cases and

TABLE 4

Total typhoid fever death rates

YEAR	POPULATION	TOTAL DEATHS		DEATH RATE		PER CENT OF TOTAL DEATHS WHICH ARE TYPHOID	AVERAGE NUMBER COLI PER 100 CC. CLEAR WELL
		All causes	Typhoid fever	All causes per 1,000	Typhoid fever per 100,000		
1890	94,923	2273		24.0			
1891	96,021	2390	100	24.9	104.2	4.2	
1892	97,120	2535	36	26.1	37.1	1.4	
1893	96,749	2142	44	22.1	45.4	2.0	
1894	96,378	2180	43	22.6	44.8	2.0	
1895	96,007	2342	119	24.4	123.9	5.1	
1896	95,636	2055	64	21.4	66.6	3.1	
1897	95,265	2016	80	21.1	84.2	4.0	
1898	94,894	1904	87	20.1	91.4	4.6	
1899	94,523	1994	69	21.1	72.5	3.5	
1900	94,151	1789	37	18.9	39.4	2.1	
1901	94,996	1766	27	18.6	28.4	1.5	
1902	95,841	1626	19	17.0	19.8	1.2	
1903	96,686	1813	22	18.8	22.7	1.2	
1904	97,531	1846	24	18.9	24.5	1.3	
1905	98,376	1810	13	18.4	13.3	0.7	
1906	98,750	1774	20	17.9	20.2	0.11	
1907	99,126	1901	20	19.2	20.2	0.11	
1908	99,502	1845	10	18.5	10.1	0.54	
1909	99,878	1759	17	17.6	17.2	0.97	
1910	100,253	1944	19	19.4	18.9	0.98	
1911	101,798	2063	16	20.3	16.7	0.78	
1912	103,343	2046	18	19.8	17.4	0.88	
1913	104,888	2025	28	19.3	26.6	1.38	
1914	106,433	1922	17	18.1	16.0	0.88	
1915	107,978	2076	15	19.1	13.9	0.72	
1916	109,052	2039	7	18.7	6.4	0.34	1.16
1917	107,979	2032	9	18.7	8.3	0.44	2.33
1918	109,052	2560	11	23.5	10.1	0.43	1.08
1919	110,125	1853	11	16.8	10.0	0.59	0.08
1920	111,198	1785	5	16.1	4.5	0.28	1.31
1921	113,344	1746	6	15.4	5.3	0.34	0.21

deaths from typhoid fever. There can be no doubt that this has been brought about by the increased chlorine dosage, although in former years it had been believed, from the bacteriological evidence,

that sufficient chlorine had been added. It might be inferred from this, that our bacterial data are at fault, and that the entire number of bacteria contained in a c.c. of water is not developed on the plates. It is probable that, with a water containing as much organic matter as does the Albany water, a great deal of this organic matter exists in the form of microscopic sponge that incloses many bacteria mechanically and renders it difficult for the chlorine to penetrate into the mass and reach the bacteria therein. With the case of a high excess of residual chlorine, the gas may actually break down the organic matter and react chemically with it, and there should yet be sufficient chlorine remaining to care for the bacteria.

TYPHOID FEVER DATA

Up to 1899 when the slow sand filters were installed, the death rate from typhoid fever in Albany was as high as any city in the country. For the nine years preceding the installation of the filters, the average death rate per year from typhoid fever was seventy-seven. For the twenty-two years following the starting of the plant, the typhoid death rate has averaged sixteen per year. The death rate from typhoid has been steadily declining each year due to refinements introduced in the process. Thus for the first eleven years of operation, the average typhoid death rate per hundred thousand was 22.2; while during the last eleven years of operation the rate was but 10.9. In this latter computation the data for 1913 were not used in determining the average, as this was the year in which the plant was inundated by the flood. For the past two years the typhoid death rate per hundred thousand has been 4.3, which has been undoubtedly caused by maintaining an adequate amount of excess chlorine in the treated water at all times. While in a general way the total death rate follows the Mills-Reincke phenomenon, and there has been a steady decrease in the total deaths, yet this latter factor has not been so pronounced and clean cut as has been the typhoid fever reduction.

Albany has always been heavily handicapped in its typhoid fever record by environmental conditions. It is located in the centre of a large farming area which is also much frequented by summer visitors. It is situated on the banks of a large polluted stream, in which there is much bathing, and whose waters are used for pleasure sailing as well as general navigation. It is a large tourist centre, but, above all things, it is the hospital centre for a large country district. As a result

of these factors, many persons contract typhoid fever from bathing in river, drinking its water, and from drinking polluted water while motoring in the adjacent rural territory. Tourists contract typhoid while motoring and come to the hospitals for treatment. People from the farming districts, where there are no hospital facilities, come to Albany for treatment. As a result of these conditions, it was estimated that in 1921 that fully 80.5 per cent of the typhoid fever cases were caused by conditions outside of Albany. In 1921 the death rate per hundred thousand from typhoid fever was 5.3, but if those deaths that were caused by outside influences are deducted, the real rate would be 2.6, which is favorable when compared with that of other cities within the registration area.

It must not be supposed that it has been the improvement in the water supply alone that has caused this general reduction in the typhoid fever death rate. Great strides have been made, especially within the past five years, in the inspection and control of the milk supply of this city. Dairies furnishing milk have been carefully regulated and the method of handling so improved, as to leave little wanting in these respects. But it must be admitted, on account of the fact that water is used by everyone, that the continued improvement of the quality of the filtered water, has been a potent agency in attaining the satisfactory typhoid death rate of to-day.

COPPER SULPHATE TREATMENT

Microscopic organisms have never been a serious factor in the operation of the filters. At times the sand of the preliminary filters has become coated with fungus growths and vorticella and at one time these accumulated to such an extent as to seriously impair the operation of the plant. At this time it was decided to give the applied water a heavy dose of copper sulphate to ascertain whether the growths could be killed and flushed out of the sand by the regular wash. It was estimated that the dose amounted to 2.0 parts per million and the next day the surface of the settling basin, which had received the treatment, was literally covered with fish in a paralyzed condition swimming in a dazed state at the top. In a short while the fish began to die in great number and it was finally necessary to skim them off of the surface by the bushel. The action on the growths was marked and the beds were easily freed from their accumulation by the ordinary wash, but, owing to the killing of the fish, this method was never repeated.

The gravity impounding and also the distribution reservoirs are subject to algal infections and have to be treated on an average of twice a year each. The main organism found in large numbers is anabaena. This form of algae develops during the early summer following the first protracted heated spell, and is readily controlled by the addition of about 0.1 part per million of copper sulphate.

DETERMINATION OF THE COLON BACILLUS

B. coli have been determined by sub-culture work from lactose broth tubes, on the formation of gas within 48 hours in appreciable amount. For a number of years lactose bile was used, but it was evident that this medium was too inhibitive and its use was finally eliminated. For 15 years neutral red bile agar media has been used with great success. Comparative work with Endo's media shows the former to be far superior, especially in the case of the raw water, where on the Endo media overgrowths are likely to occur. With the neutral red bile media the colon colonies are easily differentiated and a fairly accurate count is thus obtained within 18 hours. A comparison of the number of coli produced by this method with that obtained by the index formula from the gas tubes, shows that the two agree within 25 per cent.

COLITIS AND B. WELCHII STUDIES

During the latter part of February 1920 a great many colitis cases were reported. The malady was of a mild nature and from the general distribution of the cases, the water supply was suspected. It should be borne in mind that the causes of colitis are many and obscure. It may be caused by tainted meat and fish, decayed fruit, sweet cider, impure water containing certain forms of bacterial life, microscopic organisms, and other low forms of animal and plant life. It is evident, then, that water containing any of these forms might cause this intestinal disturbance and at the same time fail of detection in the water due to the difficult technique involved.

Coincident with the Albany disturbance, the malady was being experienced at other nearby places in the Capitol District not affected by the local water supply, and also at places quite distant such as Cambridge, Mass., and various localities in Kansas. It should be taken into account that intestinal influenza was prevalent at this period, and a great many of the so called colitis cases were diagnosed

as such. It was indeed difficult to determine whether the malady was really colitis or whether the water supply was at fault.

At this period large amounts of water were being by-passed around the slow sand units from the preliminary filters without the applied water being treated with alum. Sufficient chlorine was being added to the water as is indicated by the following typical samples collected from a tap in the distribution system on different dates.

DATE	GELATIN COUNT	AGAR COUNT	NEUTRAL RED BILE AGAR		B. COLI		OXYGEN CONSUMED
			Total	Acid	1 cc.	10 cc.	
							p.p.m.
January 28	35	6	1	0	0	0	13.5
February 4	25	7	0	0	0	0	12.6
February 11	20	8	0	0	0	0	17.2
February 18	40	4	1	0	0	0	17.2
February 25	15	4	0	0	0	0	17.3
March 3	4	3	0	0	0	0	14.6
March 10	5	3	0	0	0	0	17.0

From the above table, all during the period of the malady, the tap water would be considered of excellent sanitary quality as far as the bacteriological evidence goes. The counts were all low and coli were absent in all determinations. The only suspicious factor was the high oxygen consumed factors. It is possible that the above bacteriological data were not representative and that many bacterial cells might have been enclosed within the organic particles and thus escaped the action of the chlorine gas, although the latter was maintained in excess in the treated water. It is possible, too, that the organic matter itself, being present in such large amounts in the water, might have been the cause of the intestinal disturbance by virtue of its toxic action.

Special anaerobic tests were made in milk cultures to detect the presence of B. welchii and many of these tests gave the characteristic stormy gas formation and were found to contain sporeformers. On account of lack of technique, quantitative determinations could not be made, but there is no doubt that B. welchii were present in large numbers in the treated effluent.

As soon as it was apparent that colitis was becoming uniformly distributed throughout the city, coagulation by means of sulphate of alumina was immediately begun. The result of this was to cut

down the amount of organic matter to below 10 p.p.m. and by so doing, rendered the chlorine treatment more effective. Following this there was a gradual diminution in the number of colitis cases reported until things were normal again. All the evidence seems to point to the water as the cause of the intestinal trouble, although it is somewhat circumstantial. Granting that the water was the cause, it is a most difficult thing to determine whether it was the bacteria or the organic matter that were actually responsible.

QUALITY OF THE RAW WATER

The bacteriological constituents of the raw water vary from year to year depending upon the amount of precipitation which regulates the average seasonal stage of the river. In the gelatin counts the average for the twenty-year period was 46,600 with a maximum count of 531,500 in 1907. For the past three years the counts have been below the average, which is due to the fact that there has been an insufficiency of rain during this period. The turbidity fluctuates to some extent but most of the time it is below 5 p.p.m., a factor that makes it a most difficult water to coagulate. Owing to the character of the northern watershed of the Hudson River, a great amount of swamp water is introduced into the river following heavy rains. This factor, combined with the large amounts of industrial wastes discharged into the stream, bring the organic content of the water up to a large figure during the late summer months. The average oxygen consumed factor for the past six years amounts to 14.7 p.p.m., with a maximum and minimum of 28.0 and 6.5 respectively. This high organic content has a marked effect on the coagulation, tending to retard the reaction and mechanically to enclose portions of the alum so that it is not available for coagulation. Experiments show that if the alum is violently agitated with the raw water, a much better floc is obtained and with much more rapidity. It is probable that the next improvement made to the plant will be along the lines of installing a mixing chamber of at least thirty minutes retention period.

A great deal of discussion has taken place during the past five years concerning the load carried by water purification plants. In 1914 the engineers of the International Joint Commission went into this matter rather fully and advanced the opinion that the load on a plant is exceeded if the B. coli content of the raw water is greater than 500 per 100 cc. While the recommendations of this commis-

TABLE 5

Production and cost summary

YEAR	TOTAL NUMBER MILLION GALLONS FILTERED	AVERAGE MILLION GALLONS PER DAY	TOTAL OPERATION COST. PUMPING INCLUDED	COST PER MILLION GALLONS FILTERED	REMARKS
Jan. 1, 1900 Sept. 30, 1900	3,412.5	12.5	$23,115.28	$4.40	
Oct. 1, 1901 Sept. 30, 1901	4,918.1	13.5	24,139.78	4.65	
Oct. 1, 1901 Sept. 30, 1902	4,527.4	12.4	23,495.91	5.18	
Oct. 1, 1902 Sept. 30, 1903	4,461.1	12.7	22,017.11	4.73	
Oct. 1, 1903 Sept. 30, 1904	4,803.4	13.1	22,649.90	4.71	
Oct. 1, 1904 Sept. 30, 1905	9,942.3	13.5	25,797.03	5.22	
Oct. 1, 1905 Sept. 30, 1906	5,115.9	14.0	26,986.68	5.28	
Oct. 1, 1906 Sept. 30, 1907	5,073.6	13.9	29,234.73	5.76	
Oct. 1, 1907 Sept. 30, 1908	4,724	12.9	32,119.02	6.80	Preliminary filters started
Oct. 1, 1908 Sept. 30, 1909	5,059.2	13.9	38,606.81	7.63	Disinfection begun
Oct. 1, 1909 Sept. 30, 1910	6,540.7	17.9	39,151.51	5.99	
Oct. 1, 1910 Sept. 30, 1911	7,849.9	21.5	41,736.72	5.32	
Oct. 1, 1911 Sept. 30, 1912	7,600.5	20.8	47,082.85	6.19	Coagulation with alum begun
Oct. 1, 1912 Sept. 30, 1913	7,017.5	19.2	48,460.18	6.91	

TABLE 5—*Continued*

YEAR	TOTAL NUMBER MILLION GALLONS FILTERED	AVERAGE MILLION GALLONS PER DAY	TOTAL OPERATION COST. PUMPING INCLUDED	COST PER MILLION GALLONS FILTERED	REMARKS
Oct. 1, 1913 Sept. 30, 1914	7,817.3	21.4	60,588.40	7.75	
Oct. 1, 1914 Sept. 30, 1915	7,654.0	21.0	64,370.03	8.41	
Oct. 1, 1915 Sept. 30, 1916	7,126.2	19.5	59,825.55	8.40	
Oct. 1, 1916 Sept. 30, 1917	6,911.7	18.9	69,249.92	10.01	
Oct. 1, 1917 Sept. 30, 1918	6,870.0	18.8	84,638.33	12.32	
Oct. 1, 1918 Sept. 30, 1919	6,597.4	18.1	105,399.87	15.97	
Oct. 1, 1919 Sept. 30, 1920	6,597.8	18.1	96,360.96	14.60	
Oct. 1, 1920 Sept. 30, 1921	6,653.9	18.2	130,271.43	19.58	

sion had to do with boundary waters, the tendency has been to apply this standard to all domestic waters, the idea being that all sewage might be so treated as to bring the coli content of the stream, into which the sewage is discharged, within this limit. There is no question but that such a plan would react most favorably to the average water purification plant, but, whether it could be ever worked out without extreme hardship and cost is problematical. Surely, there are some streams that are of a great deal more use economically as a disposal of sewage than they are as a source of water supply. In most cases it would be better for a community to go farther off for an unpolluted supply, than to demand that the water at its very door be rid of its pollution, when there are many other communities further up stream, using it as a means of sewage disposal. The whole question is fraught with difficulties and should be decided from the standpoint of policy, economy, and necessity.

In the case of Albany there is no question but that the load carried by the plant is staggering. During the past six years the average number of coli per 100 c.c. has amounted to 8336 with a maximum of 22,800. Such a load has imposed a grave responsibility upon the operator, but thanks to adequate design and capacity, and conscientious management, the results compare favorably with those obtained

TABLE 6

Operation data for all filters on runs completed during years noted

YEAR	NUMBER OF FILTER RUNS	TOTAL DAYS SERVICE ALL UNITS	AVERAGE NUMBER OF DAYS PER RUN	TOTAL NUMBER GALLONS FILTERED EXPRESSED AS NUMBER OF MILLION GALLONS	AVERAGE RATE PER DAY PER ACRE, MILLION GALLONS	CUBIC YARDS OF SAND SCRAPED	CUBIC YARDS SAND SCRAPED PER MILLION GALLONS PRODUCED	AVERAGE QUANTITY FILTERED PER RUN PER ACRE MILLION GALLONS
1901	104	3,235	25.1	4,318.1	2.7	7,500	1.53	67.7
1902	92	2,821	31.0	4,527.4	2.2	7,049	1.55	70.3
1903	84	2,828	34.0	4,622.4	2.3	4,922	1.07	78.6
1904	84	2,686	34.7	4,827.7	2.6	4,903	1.01	83.4
1905	98	2,699	29.8	4,963.4	2.6	5,368	1.08	73.6
1906	104	2,682	28.5	5,115.9	2.7	8,559	1.67	72.2
1907	96	2,608	27.2	5,679.8	2.8	7,155	1.26	77.1
1908	85	2,622	31.0	4,724.2	2.6	5,940	1.26	79.66
1909	74	2,685	36.4	5,068.2	2.7	4,988	0.98	100.1
1910	52	2,698	52.0	6,540.7	3.3	2,895	0.44	209.3
1911	93	2,791	30.0	7,849.9	4.0	5,505	0.73	121.9
1912	96	2,775	28.8	7,600.5	3.5	5,689	0.75	114.5
1913	80	2,789	34.8	7,017.5	3.6	4,736	0.68	124.9
1914	55	2,759	50.0	5,842.3	3.0	3,256	0.56	156.4
1915	70	2,768	39.6	6,243.3	3.2	4,143	0.66	126.5
1916	69	2,850	41.2	6,367.2	3.2	4,084	0.64	133.8
1917	76	2,811	37.0	5,863.2	3.0	4,673	0.80	110.5
1918	49	2,805	57.4	4,942.9	2.5	2,901	0.59	148.51
1919	62	2,716	43.7	5,350.5	2.8	3,670	0.69	124.26
1920	64	2,798	43.9	5,708.5	2.9	3,788	0.66	128.35
1921	55	2,730	49.6	6,774.9	2.8	3,680	0.54	148.2

at other places. Notwithstanding the fact that Albany and other places are able to make a satisfactory showing under adverse circumstances, there is no question but that the factor of safety is very small. The slightest setback in operation is apt to result disastrously. If it were not for the means provided by chlorination many a plant would have met with disaster long ago, for in many instances it is the sole means of defense, due to excessive rates of filtration and bypassing.

SUMMARY

During the twenty-two years of operation of the Albany filters, four distinct epochs are clearly marked: the slow sand period from 1899 to 1908; the period of double filtration commencing with 1908; the introduction of chlorination in 1909, with the subsequent tendency toward decreased filter efficiency; and finally the employment of coagulation followed by the by-passing of the preliminary filter effluent around the slow sand units. These successive steps, from the standpoint of pure filtration, might be considered to be retrogressive, but when looked at with a full understanding of the conditions, they are logical enough.

For ten years the plant was operated as a slow sand proposition and furnished approximately two thirds of the water required by the city. In 1908 the decision was made to filter enough water to supply the entire needs of the city. Experiments carried out indicated that preliminary filtration would double the output of the original eight slow sand filters, at a minimum of expense. After a few years of operation, organic penetration into both preliminary and slow sand units became very marked. The preliminary filters had to resort to supplemental washes by ejecting all sand outside the beds, once or twice a year; and the slow sand beds had to have the top ten to eighteen inches of the sand ejected and replaced every other year. It became most difficult to regulate the beds so that not more than one would reach a four foot loss of head at one time. At times during the winter months, six filters would go out of commission at a time, necessitating taking large amounts of gravity water of doubtful sanitary quality to make up the deficit. With the introduction of chlorination and coagulation, water from the preliminary filters became available. As the ultimate capacity of these filters was approximately 40 million gallons per day, ample water was at hand at all times for by-passing.

Before resort was had to by-passing, everything practicable was attempted with the slow sand beds to keep the sand free of subsurface clogging and the filters in operation. The beds were forked once a year. The Brooklyn method of surface washing was experimented with. The Nichols method of sand washing was introduced. Varying rates were tried and extra heavy scrapings taken off. But all of these efforts failed to keep the beds in normal condition, until finally the emergency became so acute as to necessitate by-passing immediately.

It will be seen that what really has happened, has been the slow evolution of the slow sand process into the rapid sand type. All of the steps have been logical ones based upon economy and expediency. The introduction of the scrubber units became the potential source of a much larger supply of water. The slow sand units, due to outside conditions, eventually became unable to furnish all the water required. The preliminary filters stepped into the breach, and by means of coagulation and chlorination, not only were able to make up the deficit, but were also capable of furnishing a much more attractive water.

As to the future, it is likely that changes will be made to the basin and to the rapid filters so that they will become typical mechanical filters. This may be accomplished at a reasonable cost, and then the money now expended for labor in connection with the operation of the slow sand filters will be saved.

In conclusion, it is fitting that appreciation should be expressed of the part played by Mr. Wallace Greenalch, Hydraulic Engineer, of Albany, N. Y., in the development of the Albany Filters. As Superintendent of Water Works and later as Commissioner of Public Works, Mr. Greenalch was in charge of the design of all improvements made from 1905 up to 1922. It is mainly due to his ability as a designer and to his broad minded policy as an executive, that the local plant has been maintained in a state of creditable efficiency in the face of many obstacles.

THE DISINFECTION OF PUBLIC WATER SUPPLIES AND ITS RELATION TO PUBLIC HEALTH[1]

By C. A. Jennings[2]

Chlorine, a greenish yellow gas, was discovered in 1774 by Scheele, a Swedish chemist. One volume of liquid chlorine is equivalent to 455 volumes of chlorine gas. Chlorine was formerly produced by chemical means, but, during the last few years, it has been manufactured by the electrolytic decomposition of salt brine. Until recently, chlorine was known principally through its use in the form of chloride of lime (bleaching powder, hypochlorite of lime or hypo). This is produced by the action of chlorine gas upon slaked lime in lead-lined chambers. Coincident with the development of the electrolytic method of producing chlorine, there came the development of the machinery for liquefying the gas. As a result, chlorine is now shipped in steel drums of various capacities, including tank cars containing 15 tons. As shipped, it is in liquid form, under a pressure of about 80 pounds, the liquefied gas is dry and is between 99.5 and 100 per cent pure chlorine. The variation in the degree of purity is slight. As long as the gas is dry it will not corrode most metals.

In 1906 one of the filter companies conceived the idea that drinking water could be made out of the foul, fermenting liquid called water in Bubbly Creek or the Stock Yards Slip, a branch of the Chicago River. After some ten months of experimenting, work was started on a 5,000,000 gallon per day mechanical filtration plant. Upon its completion, it was necessary to carry on experiments for a long period of time, during which all known processes of water treatment were tried with only partial success. As a last resort, in the summer of 1908, experiments were made with hypochlorite of lime or hypo, as a germicidal agent, at the suggestion of Mr. George A. Johnson (later Colonel Q.M.C.) Consulting Engineer. The writer was employed at the time as a sanitary engineer by one of the three

[1] Read before the Iowa Section meeting, Omaha, Neb., November 2, 1921.
[2] Sanitary Engineer, Chicago, Ill.

companies interested in the experiments. The results were extremely gratifying and there followed the development of the process of disinfecting water by means of chlorine compounds, specifically hypochlorite of lime or hypo. Within a month, the water supply of Jersey City, N. J. was being sterilized. Soon Little Falls, N. J. adopted this treatment and, one after the other, cities all over the United States began using hypo. Before three years had passed, there were more than 500 cities disinfecting their water supplies by means of hypo.

Previous to this development, water supplies that needed purification were treated by storage, plain sedimentation, sedimentation and filtration, coagulation and filtration, etc. If a well water supply or a clear mountain stream or clear lake supply became contaminated, there was only one thing to do, namely, to filter the supply, even though it was already a clear water. Often this placed a heavy financial burden upon municipalities and, furthermore, a filter plant required months for construction. Disinfection by hypochlorite of lime found widespread favor especially in such cases. The standards of sanitary science had increased along other lines and now it was possible to make more stringent regulations regarding the quality of water supplies. The surface water supplies were becoming more and more open sewers, as a result of increased urban population, the sewering of most communities bordering upon the sources of water supplies and the increasing amount of trade wastes discharged into waterways. Disinfection of water and sewage came at an opportune time. It was adopted as an adjunct to filtration and other forms of water purification. At no time have the advocates of water disinfection argued that disinfection was a substitute for filtration. The principal function of filtration is clarification and incidentally a considerable bacterial reduction takes place, but this is not selective as to the kind of bacteria removed. The only function of water disinfection is to kill bacteria. It was soon proven that this treatment had a selective action on the disease producing organisms. This made it an invaluable adjunct to other purification systems.

In 1912, the first control apparatus for liquid chlorine or chlorine gas was installed. The use of a chlorinator handling a pure gas provided accurate knowledge at all times of the quantity of chlorine used, elimination of uncertainties as to the strength of the chemical being used; overcoming the odor of hypo and its corrosive action on metals, elimination of mixing chemicals in solution tanks, lower cost

of treatment and the fact that there was no deterioration in the strength of the disinfecting chemical in use or in storage. All these points showed the superiority of chlorine over hypo. At the present time there are about 2000 cities using liquid chlorine for water disinfection and few still use hypo. In order to conceive of the quantity of water sterilized daily by liquid chlorine, it is estimated that this would be equivalent to the amount of water passing over Niagara Falls in one hour, in other words, about four billion gallons.

Water borne typhoid fever epidemics are on record during many years. They take place even now, but there is no excuse for them today or for their assuming any degree of severity. Liquid chlorine treatment safeguards the public against such occurrences.

Shortly after Christmas, 1885, a man living above the City of Plymouth, Pa. returned home and took to his bed with typhoid fever. His excreta, unsterilized, were deposited upon the snow covered banks of a mountain brook which emptied into a lake or reservoir, from which the water supply of Plymouth was obtained. In March there occurred the annual spring thaw. The excreta entered the brook and then the reservoir. The resultant epidemic caused 1000 cases of typhoid fever and 114 deaths in this town with a population of only 8000. One person out of every eight had typhoid and one out of every 70 died from it. Continuous disinfection of the water supply at that time would have prevented such a terrible catastrophe.

Ithaca, New York had a typhoid epidemic similar to the one at Plymouth.

Two interesting epidemics occurred from a more unusual and more difficult cause to locate, one at Elgin and the other at Bloomington, Illinois; both within the last few years. At the Elgin Watch Company, the drinking water supply from the city mains was pure. An industrial supply was pumped from Fox River for manufacturing purposes, fire protection, etc. This supply was contaminated with the sewage of Elgin and other cities. There was a cross-connection between the two systems with a check valve in the line to prevent the river water, which was under considerably higher pressure, from being forced back into the city mains. The purpose of the cross connection was to insure the plant fire protection at all times, even in the event of the failure of their own private system from Fox River. This is common practice with manufacturing concerns, as it enables them to secure a lower fire insurance rate. On one occasion the

check valve did not seat tightly and a serious epidemic occurred among the employees. The damages paid by the company are said to have exceeded $200,000.00.

At Bloomington, Illinois, the Chicago & Alton R. R. shops had a cross connection with the city water supply. On one occasion their creek supply failed and they pumped for industrial purposes from a 33 inch outlet sewer, the contents being a mixture of sewage and creek water. The check valve between the two systems did not seat tightly and the grossly contaminated water entered the drinking water system. This caused some 400 cases of dysentery, 153 cases of typhoid, and 21 deaths. It is estimated that the damages ultimately to be paid by the C. & A. R. R. Co. will exceed $175,000.00. In some States, notably Minnesota, cross connections of this sort are absolutely prohibited by law and the State Boards of Health make inspections to see that this law is complied with.

Several large manufacturing plants with dual water systems such as the Universal Portland Cement Company at Buffiington, Indiana and the B. F. Goodrich Company at Akron, Ohio chlorinate the industrial water supply. If workmen use this water for drinking purposes, in spite of notices to the contrary, the water would be innocuous and no disease would result therefrom. Most manufacturing establishments find it profitable to take this precaution.

The water supply of Lansing, Michigan is obtained from wells in five different sections of the City, all wells being about 450 feet deep. The mains are all interconnected. It seems that one of the wells had a leaky casing in the summer of 1919 when the river was high. The high river backed up one of the sewers, sewage leaked out through the joints in the sewer pipe, this sewage permeated the soil and found entrance into the suction pipe of the deep well. The entire city water distribution system became contaminated, causing 3000 cases of dysentery, 82 cases of typhoid and 11 deaths. Liquid chlorine treatment was installed immediately at Lansing and has been used continuously since that time as health insurance against the possible return of similar conditions.

At Tonawanda, N. Y., warnings had been given frequently by the State Department of Health from 1912 until 1919 to the effect that their water supply from Niagara River should be purified. An accident to the intake precipitated the epidemic about which they had been warned and during the months of July, August and September, 1919, there were 236 cases of typhoid. Liquid chlorine

treatment was installed *after* the epidemic had been discovered and this brought it to a sudden termination. It should have been installed at the time the city received its first warning.

Through carelessness, the chlorine apparatus at Alpena, Michigan, was not operated for eight days in December, 1919, because the supply of chlorine had become exhausted and no attempts were made to replenish it from any city nearby using the same treatment. Nine people paid for this error with their lives and there were 107 cases of typhoid. Civil action was brought against the city and the city manager was discharged. A duplicate automatic chlorinator was immediately ordered to make certain that there should be no cessation in the treatment due to the possible failure of one of the chlorinators.

At Pittsburg, California, the chlorine apparatus was out of service for one day a few months ago. It was shut off while making some repairs to a chlorine cylinder. Untreated water was pumped into the mains and no notice was given to the consumers to boil the water. Out of a population of 5000 there were 100 cases of typhoid, although the apparatus was out of service only one day. Since that time Pittsburg has been sued by 21 people who were sick and the damages claimed amount to $140,000.00. A second or reserve apparatus was installed *after* the epidemic.

In May and June, 1920, Greenville, Kentucky, had 61 cases of typhoid and 7 deaths, and Xenia, Ohio, in August and September, 1913, had an epidemic of 44 cases of typhoid fever. In each case this was due to the use of hypochlorite of lime, of unknown strength and not having any check on the amount being applied. The Ohio State Health authorities reported: "It is advisable that the company abandon the hypochlorite method of disinfection and employ the more dependable and up to date method using liquid chlorine" (Municipal Journal, January 11, 1919). Since these two epidemics each city has installed chlorine control apparatus for liquid chlorine.

The population of Salem, Ohio, is 10,000. During October and November, 1920, there were 6000 cases of dysentery, 900 cases of typhoid fever and 50 deaths. The water supply was from wells and had always been considered above suspicion. Sewage found access to an abandoned pipe leading to the common suction well and so contaminated the entire system. The Bulletin of the State Board of Health of Ohio pointed out that, giving due weight to the number of lives lost, number of people who were sick and recovered, the

funeral expenses, doctor fees, loss of time of wage earners, expenditures for medical services, drugs, nurses, etc., the appropriations made by the State and by the Red Cross, the Salem epidemic showed a cost of *four hundred and fifty thousand dollars* ($450,000.00). Chlorine control apparatus installed *after* the epidemic cost about $900.00 each. The daily cost of treating the entire city water supply of Salem will be less than $1.00. With such a small investment for apparatus and an expenditure of $350.00 per year, the Salem Water Supply would have been made safe and saved the $450,000.00 as well as the lost lives. Damage suits aggregating nearly $300,000.00 have been filed against the City of Salem as a result of this epidemic (Ohio's Health, June, 1921).

Even a filter plant requires chlorine as a final or auxiliary treatment. In November, 1920, the chemist of the filtration plant at Anderson, Indiana, shut down the chlorine apparatus and allowed it to be idle for 20 days. Following this there were 18 cases and 2 deaths from typhoid fever.

The deep well water supply of Corning, New York, became contaminated as a result of a flooded condition of the adjacent river. The inhabitants suffered an epidemic of typhoid fever, even though this supply had never been contaminated before and it was obtained from deep wells. Since the epidemic there has been installed chlorine control apparatus in duplicate.

Conifer, N. Y., a small town, experienced a disastrous epidemic of typhoid in the autumn of 1920.

In 1907 the census registration area showed a population of 41,758,000, with a typhoid death rate of 30.3. In 1919, the rate had decreased to 9.2 and the population canvassed was 85,148,000. This represented a saving of lives equal to 21.1 for each 100,000, population or, on the basis of a population for the United States of 110,000,000, the saving amounts to the enormous total of 23,200 lives. In other words, if there had been the same typhoid death rate throughout the country in 1920 as that in the registration area for the year 1907, namely, 30.3, there would have been 23,200 more deaths from typhoid fever than actually occurred. This represents a saving to the country of the enormous total of $116,000,000.

It is probable that no two water works pumping stations are identical in layout of pumps, pipe lines, etc., nor in the operating conditions. For this reason a special study must be made of each proposed installation of chlorine equipment. The apparatus adapted

to the local conditions should be specified and the proper method and location of installation detailed. Some conditions necessitate the application of the chlorine as a gas, others as a solution. Often there is no way in which to apply chlorine by gravity and a positive head or pressure at the point of application must be overcome. In larger cities the amount of chlorine used daily may be considerable, comparatively speaking. In many of the smaller cities, the volume of the water treated is so small and the dosage of chlorine so slight, that it may entail difficulties in the control of such minute quantities of chlorine. For example, the smallest chlorinator has a minimum capacity of 0.01 pound of chlorine per day or 0.007 ounce per hour. This is an extremely small amount of gas to regulate accurately. For the average water supply this would sterilize water at a rate of 5000 gallons per day or about 4 gallons per minute. It is not considered a practicable proposition to try to chlorinate smaller quantities of water.

Some waters with low turbidity, color, organic matter and unoxidizable mineral matter require small amounts of chlorine for proper disinfection, possibly as little as one pound per million gallons or 0.12 part per million. There are highly colored and turbid waters and even some clear waters with large amounts of organic or oxidizable mineral matter that require several times this amount of chlorine for proper disinfection. Here again it is necessary to make a study of the water to be treated and to determine upon the proper rate of application. The average amount of chlorine used in water supplies is probably close to 2.5 pounds per million gallons or 0.3 p.p.m. In the regular operation of water treatment plants it is a simple matter to determine if the correct quantity of chlorine is being applied, without waiting for the results of a bacteriological examination. This is accomplished by testing the treated water for free or excess chlorine by means of the orthotolidin or starch iodide methods. Quantitative results may be secured if desired. At the current price for chlorine, the cost of disinfecting the average water supply will approximate 30 cents per million gallons. Ordinarily, the time period of reaction is short, varying from a few seconds to 15 minutes, depending upon the character of the water treated, quantity of chlorine used, temperature of the water, etc. Ordinarily chlorine is applied to the water as it is being pumped into the distribution system, thereby not requiring reaction chambers.

The city of Chicago has made a thorough study of the application of chlorine to its water supply. There are ten pumping stations taking their supplies from five cribs, the distances from shore varying from two to four miles. The highest recorded death rate from typhoid fever in Chicago was in 1891 when the figure reached 172 per 100,000. Various remedial measures were taken subsequent to this and, beginning in 1900, these measures were very effective, such as the opening of the Drainage Canal and thereby diverting the city sewage from Lake Michigan into the Chicago River and eventually the Mississippi River. The first preliminary work of disinfection of the water supply was done in 1912 at some of the cribs. By December 1916, chlorine control apparatus had been installed in all of the pumping stations, Since that time all of the water pumped has been chlorinated.

For the period 1906–1911 before disinfection, the average annual death rate was 14.9 per 100,000. During the years 1912–1916, while experimenting and equipping the stations with chlorinators, the rate dropped 50 per cent to 7.1. For the years 1917–1920 inclusive, while sterilizing the entire water supply continuously, the rate has been 1.35, placing Chicago in a very enviable position. It would seem that water borne typhoid fever has been practically eliminated in Chicago. Sanitarians feel that there is a certain "residual" amount of typhoid fever which may occur in cities with absolutely pure water supplies. Chicago has approached or has possibly reached that stage. The following statements are quoted from "A Report on Typhoid Fever and its Control in Chicago" by Dr. John Dill Robertson, Commissioner of Health, Chicago, dated 1919:

> In Chicago during the first nine months following complete chlorination of the water supply, which was consummated in the latter part of 1916, the death rate from typhoid fever was reduced by 71.44 per cent. Undoubtedly the application of chlorine treatment has contributed materially to the very gratifying reduction which has placed the City of Chicago in the lead of all cities of its class in the United States during the present year. It can be demonstrated that many times the cost of chlorinating the water has been saved to the people of Chicago in the saving of lives and in the prevention of sickness. The use of chlorine in liquid form has now become widely prevalent and is approved by sanitarians and health authorities generally. The marked reduction of the typhoid fever mortality in Chicago shows emphatically the efficacy of the measures employed to control the disease, such as the chlorination of the water supply, control of lake dumping, pasteurization of milk, campaign against the fly, etc.

On the basis of the statistics, and making suitable allowance for the change in the population of Chicago, it would appear that if the same typhoid death rate had prevailed during the period 1917–1920 as in the period 1906–1911, before chlorination was put into use, 364 more people would have died each year or 1456 for the four year period. Using the commonly accepted figure of $5000.00 as the value of a human life, it is evident that Chicago was saved $1,820,000.00 annually or $7,280.000.00 during the four years, by reducing the average typhoid death rate from 14.9 to 1.35 per 100,000 population. Water disinfection by means of liquid chlorine, although not solely responsible, has been in a large measure the cause of the remarkable lowering of the Chicago typhoid death rate. What has been accomplished in Chicago has been duplicated in many other cities in this country where chlorine disinfection of the water supply has been practiced. A careful study of typhoid statistics will prove the accuracy of this statement. Liquid chlorine treatment has been one of the most potent agents in the reduction in the typhoid as well as in the general death rate throughout the country during the past few years. This would be in line with the Mills-Reincke phenomenon, which indicates that, by eliminating intestinal disorders, there is accomplished a material reduction in various other seemingly unrelated death rates.

Some cities have had specific problems to solve in connection with the disinfection of their water supplies. For example, there are times when the chlorinated water at Milwaukee, Wisconsin, irrespective of the amount of chlorine applied, tastes so strongly that it may hardly be used for drinking or cooking purposes. Study of this problem has proven this to be due to the discharge of trade wastes into the lake or into one of the rivers emptying into the lake. The first waste which caused trouble was from a phenol or carbolic acid plant. After eliminating this, the taste returned and this time it was traced to a gas house on one of the rivers. The plant was discharging coke quenchings into the river and when the wind was in a certain direction, this river, which was practically stagnant, polluted the lake. The dissolved matter found its way to the water works intake and caused the city water to have a noticeable taste after chlorination. Remedial measures are being considered at the present time.

At Marquette, Michigan a creosote plant is located a few miles from the city and from the waterworks intake. When the wind is

from a certain direction, the chlorinated water develops a decided taste and odor, due to creosote wastes discharged into the lake. The owners of this plant are owners of one of the large iron ore companies and previously refused to treat their creosote wastes to render them less obnoxious, on the ground that these wastes are not harmful to the health of the people. In fact they claim that they can prove that a small amount of creosote is beneficial. Moving the intake at Marquette further out into the lake and into deeper water has had no beneficial effect at these times. Recently they cooperated with the Michigan State Board of Health to eliminate these wastes and the results are promising.

Cleveland, Ohio, Indianapolis and Anderson, Indiana, have had experiences somewhat similar to Milwaukee.

A special use for chlorine was developed at Champaign, Illinois in connection with the Champaign & Urbana Water Company supply. The water is obtained from wells containing 2.0 p.p.m. iron. Several years ago an iron removal plant was installed and for about two years this gave good results, removing about 90 per cent of their iron. Then there appeared in the mains and reservoir growths of crenothrix. Various expedients were tried and finally liquid chlorine was given a trial. The results were strikingly successful from the start. Beneficial results were obtained immediately in reducing the growth of crenothrix. As a result of these encouraging experimental data, a permanent liquid chlorine apparatus was installed and has been in successful operation for several years. This has entirely eliminated the crenothrix growth. In this case, chlorine was used not as a germicide but to kill crenothrix. Similar installations for crenothrix elimination have been installed at Frankfort, Indiana and Eau Claire, Wisconsin.

During the last few years there have been advances in swimming pool sanitation. Radical changes have taken place in the design of pools as well as in the treatment of water in the pool. Formerly little consideration was given by the average person to the sanitary condition of the swimming pool. Now such organizations as the International Committee of the Y. M. C. A., as well as many colleges, boards of education, etc. will approve of no plans for swimming pools without the incorporation of a recirculating pump, filter and disinfection treatment by liquid chlorine. The method of operation is to withdraw water from the deep end of the pool by the recirculating pump at a rate sufficient to empty the pool in about 18 hours

(the rate will depend upon the probable number of bathers), to pass this water through a filter for clarification purposes and then to treat it with a solution of chlorine on its way back to the shallow end of the pool. This procedure is intended to keep the water in the pool clear and bacterially pure all of the time, irrespective of the number of bathers using the pool. By this system of recirculation, filtration and disinfection, a large financial saving may be effected yearly, in view of the fact that it is not necessary to empty the pool entirely except after longer periods of time. Without this system the pools are emptied weekly and in some cases more often. They are scrubbed down, fresh water placed in the pool and this water must be heated from the temperature of the city water up to about 74°. For the average sized pool this will cost about $20.00 for the coal alone for each refilling. This figure does not include the cost of the water nor the labor involved. Ordinarily the entire installation of a pump, filter and chlorinator may be saved in a comparatively few months. Furthermore, the quality of the water in the pool is much better continuously than without this method.

Chlorine disinfection of swimming pools is satisfactory and efficient because of its low first cost and negligible operating cost (about 5 cents per day); the results are positive; it is possible to determine by the previously mentioned chemical tests whether or not the proper quantity of chlorine is being applied; the strength of the chemical is constant; the rate of application may be changed as desired; the efficiency of the treatment is not dependent upon the production of a clear and colorless water, as is the case with some of the other methods of pool disinfection; not only is the recirculated water sterilized, but this water is charged with sufficient excess chlorine to act as a sterilizing agent upon the entire pool. Indiana and Minnesota Universities, Chicago Central Y. W. C. A., Great Lakes Naval Training Station, Toledo Y. W. C. A., Duluth Boat Club and St. Louis Y. W. C. A., are some of the pool installations in this section of the country using chlorine.

Liquid chlorine has been successfully used in the New England states to kill anthrax, a deadly spore forming type of bacteria found frequently in the tanning industry.

Chlorine has been used to a much more limited extent in the treatment of sewage. Sewage treatment (purification) is aimed essentially at the elimination of nuisances, by reducing the suspended organic matters in the raw sewage and is not designed to

effect a bacterial reduction, except incidentally. Chlorine is a germicidal treatment and, as such, is used as an adjunct to sewage treatment plants to protect water supplies, shell fish beds, etc. In some cases, chlorine has been used on crude sewage, but, because of the large particles of suspended matter in raw sewage, it is not recommended as standard practice. There may be some isolated cases where such treatment is called for.

Among the Iowa Cities using liquid chlorine for water disinfection are: Akron, Avoca, Bedford, Boone, Cedar Rapids, Chariton, Clarinda, Corydon, Cherokee Hospital, Centerville, Creston, Council Bluffs, Cedar Falls, Des Moines, Dubuque, Davenport, Everly, Fort Dodge, Iowa City, Jefferson, Keokuk, Lenox, Muscatine, Newton, Ottumwa, Sanborn, Storm Lake, and Waterloo.

Of the various sanitary measures adopted in recent years, liquid chlorine disinfection of water supplies has been instrumental in the saving of thousands of lives throughout the country, by the reduction of the typhoid fever death rate. The American City Magazine stated recently: "The City that chlorinates its water supply is providing itself with good insurance against a criminally high death rate from typhoid fever." The Michigan State Board of Health Bulletin recently stated: "City officials are learning that it is much cheaper and safer to chlorinate water supplies than to try to keep the source in a state of natural purity. During 1920, typhoid fever cost citizens of the State more than $1,500,000.00." Liquid chlorine water disinfection is a municipal life insurance policy costing a premium of 2 cents per capita per year—an insurance policy that should be purchased by the officials of every city having a water supply upon which any suspicion as to its sanitary quality may be cast. The premium is small—the benefits immeasurable.

GAS PRODUCTION BY AN AEROBIC SPORE BEARING BACILLUS

By Henrietta Lisk[1]

In 1897 Arthur Meyer (9) of the University of Marburg isolated from decaying carrots a gas producing, aerobic spore bearing bacillus, to which he gave the name of Bacillus asterosporous. Migula (11) gives the following description of this organism:

> Motile rods; usually single, rarely in short chains; 1–1.3 μ in width by 3–6 μ in length. Just before spore formation, rods are non-motile and swelling. Spores oval, with elongated ridges; in cross section, star shaped; formed at the poles. Flagella are found all over the body of the bacillus.
>
> On pieces of boiled carrot, there develops at the base of inoculation a gray, glassy, mucilaginous heap, which spreads so that after five days there is a thin coating of jelly over the entire medium. Gas blisters form in the growth, so that it takes on a much whiter appearance. The growth dissolves the central lamellae of the cells so that the carrot gradually softens. It is to be noted that the culture retains a pleasant odor. In five days rods forming spores, free spores, and motile rods are found in the culture. In dextrose agar stab cultures, there is after three days a uniform development of the bacteria in the stab. On the surface of the agar, there appears a small yellowish mound covered with flat concentric circles. In an agar slant, a thin transparent whitish coating appears. A dextrose gelatin stab culture, after two days, showed three-fourths of the stab about to dissolve. At the same time the stab was irregularly funnel shaped and gas producing. In various solutions the bacillus will grow with great turbidity.

In the fifteenth annual report of the Delaware College Agricultural Experiment Station, Newark, Delaware, 1903, Frederick D. Chester gave the morphological and cultural characteristics of Bacillus asterosporous as obtained from the study of a culture secured from Kral's Laboratory.

In 1909 G. Bredemann (4), assistant in the Botanical Institute of the University of Marburg, published the results of his study of Bacillus asterosporous. Bredemann examined one hundred and thirty-eight samples of soil from widely separated portions of the

[1] Department of Bacteriology, School of Hygiene and Public Health, Johns Hopkins University, Baltimore, Maryland.

world, i.e., Germany, India, China, United States, etc., and found Bacillus asterosporous in thirty-four of these specimens. He points out that the bacillus was never found in uncultivated soil, such as sea sand, and earth from swamps and forests, but only in cultivated soil, such as fertilized fields, and was, therefore, probably introduced through the agency of man.

Bredemann states that other authors who have found Bacillus asterosporous are Gottheil (6) who found it frequently in field earth, and in soil from the Botanical Gardens of the University of Marburg; Ankersmit (2) who isolated the bacillus from the alimentary canal of cattle; Behrens (3) who found it in decaying flax; Aderhold (1) and Haselhoff and Bredemann (7) who found it in decaying vegetables.

Bredemann, in studying the variations and nitrogen fixing power of Bacillus asterosporous, used twenty-seven cultures, one of which was a transfer from Arthur Myer's original culture isolated from the carrot. He found the variations no greater in the number of cultures used than might be expected from one specimen. He grew the bacillus under anaerobic conditions as well as aerobic, and found that he obtained equally strong growth with both methods.

Bredemann's description of the morphological and cultural reactions of the Bacillus asterosporous agrees with that of Migula in the main points. He states that the peculiar formation of slime, and solution of carrot substance with formation of an odor, were constant characteristics of his cultures. In anaerobic conditions the most typically similar characteristic was the appearance of the growth in agar. The colonies showed marked finger like extensions, which were raised, wormlike, and clubbed at ends, with sometimes a purplish red color appearing in places. He found that the number of ridges appearing upon the spores varied from 8 to 14. Bredemann states that Bacillus asterosporous grew readily in nitrogen free media, and had the power of nitrogen fixation. He found that cultures which had lost this power became regenerated on being grown in media which contained a little soil.

Gas production by an aerobic spore bearing bacillus was reported in 1918 by E. M. Myer (10) who in the course of routine water examination isolated this bacillus eight times from the tap water of Newport, Kentucky, during the period from January to April, 1917. At a later period he isolated the same organism three times, once from the tap water of Covington, Kentucky, and twice from raw tannery wastes. Myer states that Dr. J. S. Bolten, also of the

Laboratory for Field Investigations of Stream Pollutions, isolated the same or a similar organism from a sample of sewage taken from Mill Creek in 1916.

In 1919, C. Leroy Ewing (5) reported the isolation from Baltimore drinking water of a bacillus, which he believed to be identical with that of E. M. Myer. The presence of this organism was noted only during the season of heavy rains—March, April and May.

Both E. M. Myer and Ewing stress the importance of microscopic examination of lactose fermenting, Gram negative (48 hours) bacilli for spores, for, during the times of its appearance, this bacillus might cause considerable error in the colon index in routine water examination.

An aerobic spore bearing bacillus which produces gas was isolated by the writer in January, 1922 from a sample of milk from Fort McCoy, Florida. Before plating, this milk had been subjected to 80°C. for half an hour. When gas production in the aerobic spore bearer was detected, a broth culture was shaken by a mechanical shaker for fifteen minutes, and then plated. All colonies appearing on the plates were fished and found to be identical with the original culture. The morphological and cultural characteristics of the bacillus were found to be as follows:

Morphology and staining properties—twenty-four cultures at 37°C.

In plain agar vegetative rods predominate. These are medium length, rather slender (2.1μ in length by 0.675μ in width to 3.5μ in length by 0.7μ in width), frequently curved and slightly broader at one end than the other. Fusiform rods are occasionally seen. A darkly staining granule is usually conspicuous near the center of the vegetative rods. No capulse can be demonstrated in milk cultures. The bacilli are actively motile, and when stained by Loeffler's method show ten peritrichic flagella. The bacilli stain readily with all ordinary stains and are Gram positive in twenty-four cultures.

Spore formation. Spores are formed in less than twenty-four hours, and are present in large numbers in forty-eight hour cultures. They are central, excentric or terminal, and are much wider than the vegetative rods. Free spores are 2.1 microns in length by 1.4 micron in width, oval and smooth in outline.

Agar colonies. Very small, irregular, or round, translucent, thin white colonies, adhering to the agar. Rarely more than $\frac{1}{8}$ inch in diameter—usually smaller. Occasionally delicately filmy fernlike colonies $\frac{3}{8}$ of an inch in diameter are found.

Agar slant. In twenty-four hours, growth is thin, beaded, translucent and adheres to the agar. In forty-eight hours the growth usually spreads over the media at the base of the slant, and presents an irregularly serrate outline.

Agar stab. Slight, beaded, translucent surface growth surrounding the point of inoculation. Stab thin, blade like, with crenate outline. In old cultures the crenate border is tipped, with fine bristle like projections. Gas is produced in depths of the media.

Gelatin stab. Faint inconspicuous dotted line of growth in twenty-four hours. By the fourth day a large bubble like depression is found immediately below the surface, becoming gradually filled with flocculent growth. Slight liquefaction appears in this area about the twelfth to the thirteenth day.

Broth. No scum. Faint dotted ring of growth appears on sides of tube in forty-eight hours and remains. Broth shows slight turbidity and sediment up to thirtieth day.

Peptone. No scum. Dotted ring appears on sides of tube in twenty-four to forty-eight hours. Slight turbidity and sediment. Ehrlich's para-dimethyl amidobenzaldehyde test shows no indol production up to twelfth day.

Nitrate broth. Sulphanilic acid plus a-amido-naphthalene acetate solution shows nitrites present on fourth day.

Voges-proskauer test. Positive on second to fifth day.

Clark and Lubs. Negative reaction.

Endo's medium. Small round colonies varying from a pin point to $\frac{1}{8}$ of an inch in diameter. Colonies reddened, but showing no sheen. Old colonies tough, raised, and with marked central depression. Gas is produced in medium.

Potato. Milky white growth appearing in twenty-four to forty-eight hours, coarsely punctate, or so foamy as to be blown against sides of tube. Gas production varies from 0 to 20 per cent in twenty-four hours and from 5 to 50 per cent in forty-eight hours. Growth becomes yellow on fourth to fifth day, and gradually darkens to brown.

Dextrose broth. Scum formed in twenty-four to forty-eight hours. Growth slimy. Turbidity great. Gas in twenty-four hours, 0 to 20 per cent, in seventy-two hours 60 to 100 per cent. Gas formula in forty-eight hour culture—$H:CO_2::20:10$.

Lactose broth. Slimy scum. Gas in twenty-four hours 0 to 10 per cent in seventy-two hours, 40 to 80 per cent.

Saccharose. Slimy scum. Gas in twenty-four hours 0 to 10 per cent, in seventy-two hours 40 to 100 per cent.

Maltose. Slimy scum. In forty-eight hours gas production 10 to 60 per cent.

Laevulose. No scum in twenty-four hours. Gas production in twenty-four hours 10 to 20 per cent.

Inulin. Scum. In twenty-four hours gas 0 to 10 per cent, in forty-eight hours 30 to 40 per cent.

Mannite. Scum. In twenty-four hours gas 0 to 10 per cent, in forty-eight hours 60 to 80 per cent.

Dextrose litmus agar slant. Slight dotted growth in twenty-four hours. Medium acid, becoming alkaline on sixth or seventh day. Gas is produced.

Russell Andrade medium. Acidity in dextrose and lactose, becoming neutral fifth to sixth day. Gas is produced.

Litmus milk. In twenty-four hours, acid but not coagulated. In forty-eight hours, reduced and softly coagulated. By fourth day the digested zone is amber, and the coagulum a pale tan. The coagulum is of a rubbery consistency and is shot with gas bubbles. About the fourteenth day the digested zone becomes a clear bright red, and remains so indefinitely. A portion of the coagulum remains undigested on the thirtieth day.

Blood serum. A dotted thin growth appears in twenty-four hours. The medium becomes translucent beneath the growth but shows no liquefaction at any time.

This gas producing bacillus was grown under anaerobic conditions by the following method, as described by the writer in the American Journal of Public Health, May, 1922.

Melted agar was poured into a tumbler to the depth of half an inch, inoculated heavily and allowed to harden. A crystallizing dish was filled with paraffin oil, and a small piece of phosphorous was floated on the surface by means of a cardboard float. The phosphorous was ignited, and the tumbler containing the inoculated agar quickly inverted over it. As the oxygen was removed from the tumbler, the paraffin oil rose to take its place (one fifth the height of the glass). The culture was thus sealed from the air by the nitrogen content of the glass, the fumes of phosphorous trioxide, and the layer of paraffin oil within the tumbler and the considerable quantity remaining in the crystallizing dish. The plate was then incubated at 37°C. for four days. Upon examination, the surface of the agar was found to be covered with small, thin, white colonies, round and entire, or very irregular, with thin finger like projections. Microscopic examination showed the typical bacilli and spores as previously found. Gas was produced in the medium. A culture was also grown anerobically by the method of MacIntosh and Fildes, (Lancet, 1916, 1, 768), i.e., the palladium wool method for combining hydrogen jet with oxygen in an air tight vessel.

The isolation and study of this bacillus was carried out in the Bacteriological Laboratory of the School of Hygiene and Public Health through the courtesy of Dr. W. W. Ford.

Conclusion: With the exception of the peculiar ridged appearance of the spores of Bacillus asterosporous described by the German authors, the morphological picture agrees with that of Chester. The scanty cultural reactions given also agree with those of Chester in the main. While a few points of difference are to be noted in the description given by Chester of Bacillus asterosporous, the bacillus isolated by E. M. Myer and Ewing, and the bacillus isolated by the

writer from milk, the general resemblance is so strong as to render it quite possible that all of the aerobic spore bearing gas producing bacilli so far described have been cultures of Bacillus asterosporous.

REFERENCES

(1) Aderhold, R.: Notiz über die Verderber von Gemüsekonserven. (Centralbl. f. Bakt., Abt. II, Bd. V, 1899, p. 17, 515.)

(2) Ankersmit, P.: Untersuchungen über die Bakterien im Verdauungskanal des Rindes. (Centralbl. f. Bakt., Abt. I, Bd. XL, 1906, p. 107.)

(3) Behrens, J.: Ueber die Taurotte von Flachs und Hanf. (Centralbl. f. Bakt. Abt. II, Bd. X, 1903, p. 524.)

(4) Bredemann, G.: Untersuchungen über die Variation und das Stickstoffbin dungsvermögen des Bacillus asterosporous A. M. ansgefuhrt an 27 Stämmen verschiedener Herkunft (Centralbl. f. Bakt., 2 Abt., 22, 1909, pp. 44).

(5) Ewing, C. L.: American Journal of Public Health, vol. 9.

(6) Gottheil. O.: Botanische Beschreibung einer Anzahl sparenbildender Bakterien. (Dissert. Marburg, 1901 u. Centralbl. f. Bakt., Abt. II, Bd. VII, 1901, p. 430.)

(7) Gruber, Th.: Beitrag zur Identifizierung und Beschreibung von Clostridium Polymyxa Prazmowski. (Centralbl. f. Bakt., Abt. II, Bd. XIV, 1905, p. 353.)

(8) Haselhoff, E., and Bredemann, G.: Untersuchungen über Konservenverderber., Bd. XXXV, 1906, p. 415.

(9) Myer, Arthur: Neues über die Morphologie der Bakterienzelle und die Entwickelungsgeschichte der Bakteriensporen. (Sitzungsber d. Ges. z. Beförd. d. Naturw., Marburg, 1897, p. 49).

(10) Myer, E. M.: Journal of Bacteriology, Jan., 1918, vol. 4.

(11) Migula, W.: System der Bakterien, II, p. 528.

FILTERS FOR REMOVING OIL FROM BOILER FEED WATER[1]

By Leonard A. Day[2]

Removal of oil from the condensate of the large pumping engine of water works is a problem that has no doubt confronted many a pumping station engineer. A brief description of a method successfully in use for about twenty years at the St. Louis Water Works may serve as a help to the engineer so troubled.

Choosing the pumping station at the Chain of Rocks for example, where there are compound duplex pumps in service, the condensate after leaving the engine flows to a common hot well where any surface accumulation of oil is skimmed off as often as it may appear necessary. The hot well is kept at a constant level by the make up water whose rate of feed is float controlled. From the hot well, the boiler feed pumps deliver the condensate through filters and closed heaters to the boilers. The filters remove all remaining objectionable oil from the condensate on its way to the boilers.

A single filter unit is shown in detail, in the accompanying drawing and is made up as follows:

A steel shell is partially filled on the bottom with concrete on which the bronze spider (1) rests, the spider being a group of connected pipes on which are mounted strainers through which the filtered water is collected. Forty inches of coke is filled on top of the spider and 8 inches of gravel above the coke, the rest of the space above is filled with water. Condensate enters at the top and leaves through the strainer system at the bottom. The filters are washed once a week by reversing the flow from the bottom to the top. Hydrant water is used for this purpose through valve (2) and steam is also admitted through valve (3) for heating the hydrant water. The discharge, when cleaning, passes through sight funnel (4), and the cleaning operation is kept up until the water runs clear.

[1] Contribution No. 2, prepared under the auspices of Committee No. 7, on Pumping Station Betterments, Council on Standardization.

[2] Chairman of Committee on Pumping Station Betterments; Mechanical Engineer, St. Louis, Mo.

A pop safety valve (5) discharges in case of over pressure on the shell.

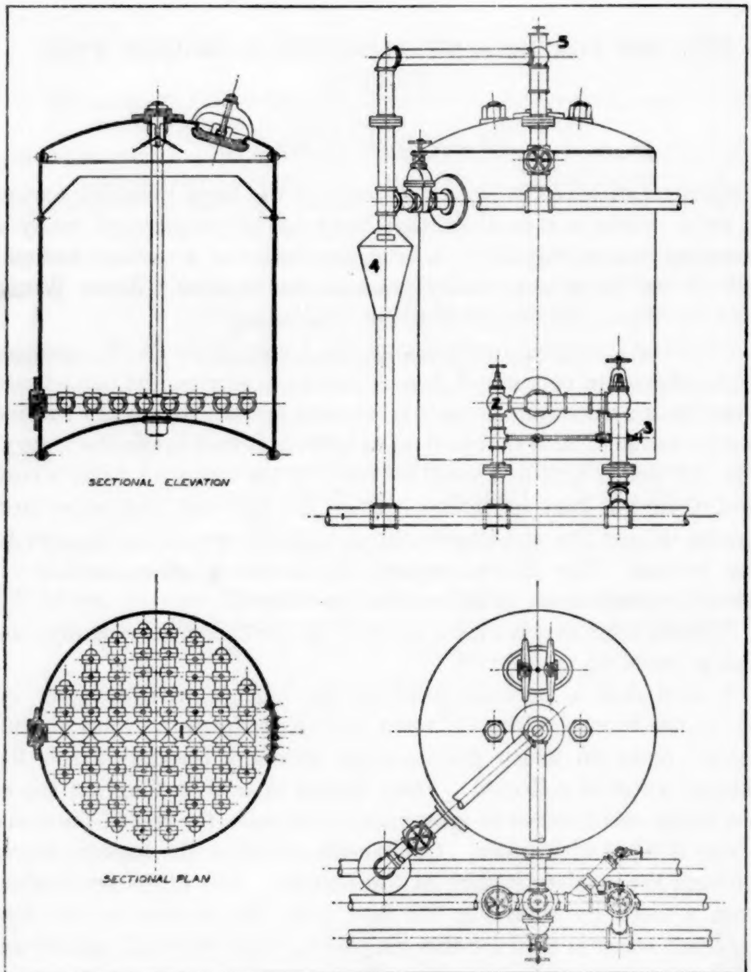

Fig. 1

Three of these filters can handle 60,000 pounds of boiler feed water per hour with a pressure loss of about 10 pounds per square inch.

WATER SUPPLY IN ITS RELATION TO SEWAGE DISPOSAL[1]

By J. Clark Keith[2]

A peculiar situation, without parallel in Canada, exists along the Canadian side of the Detroit River in Essex County. Eight municipalities with adjoining boundaries front on the river over a distance of approximately 10 miles, each with its own municipal government, but all on the same drainage basin, and each vitally concerned in its sanitation in relation to its upstream neighbor. There are no outstanding topographical features in any portion of the district, it is universally flat, the difference between extreme contours being about 25 feet. With this condition existing the problem of drainage is an acute one, inasmuch as it all must have its outlet in the Detroit River, which is the source of the district's water supply.

In the final report of the International Joint Commission in 1918, a board of advisory engineers from United States and Canada, among whom was the Provincial Sanitary Engineer of Ontario, made a résumé of testimony which was sumbitted to them which has a direct bearing on this subject and from which some excerpts are given.

> In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource and that the utilization of this resource is justifiable for economic reasons provided that an unreasonable "burden or responsibility" is not placed upon any water purification plant and that no menace to the public health is occasioned thereby.

Much discussion centered on what was implied in the phrase "burden or responsibility" and the advisory board stated that the safe loading of a purification plant was exceeded if the average number of B. coli exceeded 500 per 100 cubic centimeters or if in 0.1 cc. B. coli is found 50 per cent of the time.

[1] Presented before the Canadian Section meeting, May 12, 1922.

[2] Chief Engineer, Essex Border Utilities Commission, Canada.

In view of the progress which is being made at the present time in sanitary science, this limit or standard should be regarded as tentative. This is probably a very conservative limit, as a filter plant has been constructed on the island of Bob-lo, almost at the mouth of Detroit River, from which excellent results are being obtained.

It was further stated that

In general, protection of public water supplies is more economically secured by water purification at the intake than by sewage purification at the sewage outlet, but that, under some conditions, both water purification and sewage treatment may be necessary.

There will probably be general acceptance of the latter finding, as a temporary interruption in sewage treatment or contamination from an obscure source or a single individual might at any time endanger the health of an entire community if entire reliance is placed on sewage treatment alone.

Sewage disposal may bear a varying relation to water supply depending upon the following considerations: (1) A filtered water supply in conjunction with sewage disposal, in accord with the approved present day methods. (2) The water supply unfiltered but with effective sewage treatment. (3) The water supply unfiltered with sewage treatment which will prevent nuisances and protect fish life. In Great Britain and Germany practically all surface waters are filtered and if this principle were adopted in Ontario, then sewage treatment, to the extent of removing nuisances, might be considered effective.

The most serious pollution of any of the boundary waters is found in the Detroit and Niagara Rivers. This pollution has its origin chiefly in the sewage and storm flows from the riparian cities and towns and in the sewage from vessels. Extensive analyses were made by the International Joint Commission in 1913 and the B. coli count varied from 5 per 100 cc. at the head of the Detroit River to 10,592 per 100 cc. at Amherstburg. In 1920 a further series of analyses were made by the Provincial Board of Health, as a guide to a Board of Engineers reporting on a water supply for the Essex Border District, and there was an average increase in pollution of 50 per cent in that interval, notwithstanding extensive improvements in the sewage systems of the District.

The Border Municipalities realizing that independent action in regard to their sewage problem as affecting their water supplies

would be fruitless of concrete results, coördinated their activities by the formation of the Essex Border Utilities Commission in 1916. The town of Ford, upstream from Walkerville and Windsor, was without an adequate system of sewers and approval of piecemeal construction was withheld by the Provincial Board of Health. This condition could not be prolonged indefinitely and in 1917 an extensive report was made to the Essex Border Utilities Commission by Morris Knowles, Esq., dealing with the related questions of sewage disposal and water supply. It was recommended (1) that an intercepting sewer be constructed from Pelette Road in Ford City along Sandwich street through Ford City and Walkerville to an outlet in the Parent avenue sewer in Windsor, (2) that an intercepting sewer be constructed from 14th street in Ojibway, following Main street, Sandwich street, and Russel street with its outlet at Park street in Sandwich.

These two questions were submitted to the ratepayers of Ford, Walkerville, Windsor, Sandwich, Sandwich West and Ojibway and their construction was favoured by a vote of 7 to 1. The cost was apportioned among them, taking into consideration area, population, assessment and "capacity times distance" as bases. As an economic factor the interceptors were designed only for sanitary flow, with storm overflows into the river. These overflows are regulated by means of positive action floats and sliding gates to admit to the interceptors at all times an amount equivalent to the dry weather flow of the district. Owing to the small available slope, it was necessary to construct a sewage pumping station at Walkerville which would lift the sewage from these two municipalities about 18 feet to a sewer continuing along Sandwich street to the Parent avenue outlet. The operating cost of this station is borne by these two municipalities in direct proportion to the amount of sewage they contribute to it, records being available through venturi meters at their boundaries. The eastern section together with the Walkerville Pumping Station was completed in February, 1920. The southern section was completed in May, 1921, and, as a result, 5 miles of the river front were freed from sewage pollution, nine objectionable sewage outlets were eliminated and all the sewage from the towns of Ford and Walkerville enters the river below the intakes of the Walkerville Water Company and the City of Windsor. The quantity of sewage so diverted amounts to about 2,250,000 gallons per day, equivalent annually to the total flow of the Detroit River for ten minutes. Eventually the sewer will be constructed across Windsor

to a disposal plant in Sandwich. When the International Joint Commission issues the ultimatum that the pollution of boundary waters must cease, the Essex Border District will have the work well under way.

While the construction of these sewers was in progress, there was a periodic demand for filtration due to seasonal disturbances in the water supply. Within the past five years plans for filtration plants have been prepared for both the Walkerville Water Company and the Windsor Water Commission. Neither of these water organizations had taken any action as there was at the same time a feeling in the district that a joint plant might be constructed which would effect economies for all concerned.

Reports on joint schemes were submitted in 1917 and 1919 but they did not offer a satisfactory solution to all interested parties. In 1920, a joint board, consisting of F. W. Thorold, representing the town of Walkerville, E.M. Proctor, the City of Windsor, and Morris Knowles, the Essex Border Utilities Commission, brought in a unanimous report which they recommended from the viewpoint of economy and of the future growth of the district.

The recommendations in brief were that an intake, low lift pumping station and filtration plant be constructed at Strabane Avenue in Ford City and that filtered water be supplied through a gravity main to the pumps of the Walkerville Water Company and the Windsor Waterworks. These pumping stations would distribute water as they are now doing for the next thirty years, when an existing water franchise expires or until amalgamation of the Border Cities became an accomplished fact.

As a result of a recent conference, the question of the construction of this plant will be submitted to the electors in December next.

Notwithstanding the elimination of the sewage from the river front above the present intakes in Windsor and Walkerville, there is a growing increase in pollution. At the outlet of the Parent avenue sewer there was an average count of 10,650 B. coli per 100 cc. in 1920, a figure which could only be obtained much lower down the river in 1913. This same condition is no doubt apparent not only in boundary but in inland waters as well. The one safeguard for the health of this province would appear to be in strict provincial or international control, resulting in adequate treatment both of water supply and its complement—domestic wastes.

SOCIETY AFFAIRS

4-STATES SECTION

A meeting of the "4-States Section" was held in Baltimore on Saturday, November 18, 1922.

On arriving in Baltimore the visiting members were taken in motors from the City Hall to the Montebello Filtration Plant where, through the courtesy of the Water Department, lunch was served to all the members.

The meeting, more or less informal, was presided over by the Secretary in the absence of the President and Vice-President. One paper was read by V. Bernard Siems, "A Discussion of the Finances and Conduct of Business of a Municipally Owned Water Works, as Segregated from Other Municipal Operations." After this paper James W. Armstrong gave a short talk on the work which had been and will be done in connection with the filtration plants at Baltimore.

About 125 members were present who thoroughly enjoyed the hospitality of the Baltimore Water Department.

CALIFORNIA SECTION

The third annual convention of the California Section was held in the meeting room of the East Bay Water Company's building in Oakland, California, on October 26, 27, and 28, 1922.

One hundred and forty-two members and guests registered from all parts of the State.

The following papers were read at the various sessions:

Publicity, by Edw. F. O'Day, Director of Publicity, Spring Valley Water Company.

Pumping Machinery, by B. R. Vanleer, Ass't Prof. Mechanical Engineering University of Calif.

Purchasing, by P. W. Stamps, Pres. Purchasing Agents Association of Northern California.

Microscopic Animalculae, by C. A. Kofoid, Professor of Zoology, University of California.

Standards of Water Bacteria, by Chas. Gilman Hyde, Prof. Sanitary Engineering, University of California.

Valuations and Rates, by Chester Loveland, Consulting Engineer.

Design of a City Water System, by J. D. Galloway, Consulting Engineer.

The East Bay Filter Plant, by W. F. Langelier, Assoc. Prof. Sanitary Engineering, University of Calif.

Underground Waters, by Chas. H. Lee, Consulting Engineer.

On Friday night, the East Bay Water Company acted as hosts at a dinner given to the delegates attending, and on Saturday, all enjoyed an automobile ride around the East Bay section.

At the business meeting which was held in the Hotel Oakland on Thursday evening, the following officers were elected:

Chairman, L. M. Anderson, Los Angeles; Vice-Chairman, Fred J. Klaus, Oakland; Secretary-Treasurer, S. B. Morris, Pasadena; Executive Committee, C. B. Jackson, Fresno and Geo. W. Pracy, San Francisco.

IOWA SECTION

The eighth annual meeting of the Iowa Section was called to order by Chairman J. Chris Jensen, on November 1, 1922, at the State University of Iowa, Iowa City, Iowa. President Walter A. Jessup of the University welcomed the Section. Chairman Jensen responded to the address of welcome. The round table discussions were taken up as follows:

Storage of Water vs. Pumping for Fires.

Location Records of Water Services.

Legislative Enactment Permitting Frontage Tax or Ready-to-Serve Charge in Water Main Extensions for Municipally Owned Plants.

The Section then adjourned until 1.45 p.m. when the following papers were presented:

Tastes and Odors from Chlorination of Water, by Edward Bartow and R. M. Warren; discussion by Wm. Luscombe, George T. Prince, Jack J. Hinman, Jr., C. L. Ehrhart and Edward Bartow.

Fuel Oil Engines vs. Steam Engines for the Small Water Works Plant, by George T. Prince; discussion by R. E. McDonnell and W. M. Householder.

Who is to Blame for the Condition of the Small Iowa Water Plants? by Hans V. Pedersen; discussion by R. E. McDonnell, Wm. Luscombe, R. N. Tracy and Jack J. Hinman, Jr.

In the absence of Wm. Molis, who was to read a paper on Tubular Wells, discussion was resumed.

It was moved by Thomas Maloney and seconded by Warren J. Scott that the chairman of the meeting appoint a legislative committee to consider the points covered in the discussion of the proposed frontage tax or ready-to-serve charge for water main extensions in the case of municipally owned plants, to endeavor to secure more adequate funds and personnel for the office of the State Sanitary Engineer, and to take up such other matters as pertain to the improvement of the water service in general. Carried.

It was suggested by R. E. McDonnell that each member of the Section be a committee of one to inform the secretary of the Section of such news items as in his judgment deserve publicity, and that the Secretary endeavor to assist in securing adequate publicity therefor.

River vs. Well Water Supplies and Algae Troubles were then discussed.

The Section adjourned for supper and re-assembled at 8:00 p.m. for the following papers:

Water Works Management, by Charles B. Burdick.

In the absence of Charles S. Nichols, who was to read a paper on A Survey of the Water Supply of Iowa State College, an illustrated paper on Beautification of Water Works Grounds was given by R. E. McDonnell.

The Section then adjourned.

A special car on the Cedar Rapids and Iowa City Railway carrying the members of the Section, left Iowa City for Cedar Rapids at 8:30 a.m. on Thursday, November 2. Immediately upon arrival at Cedar Rapids the members proceeded to the Chamber of Commerce and continued the session of the Section. Papers were read as follows:

Some Experiences with Anaerobic Spore-Forming Bacteria at Minneapolis, by Frank Raab; (read and explained by Max Levine); discussion by L. I. Birdsall, Max Levine, Jack J. Hinman, Jr., H. F. Blomquist, F. D. H. Lawlor and Dow R. Gwinn.

Some Observations on Shallow Wells as Sources of Municipal Water Supplies, by Earle L. Waterman; discussion by Max Levine, Jack J. Hinman, Jr., Dow R. Gwinn, Edward Bartow, C. O. Bates and R. E. McDonnell.

Lime Softening of the Missouri River Water, by Joseph B. Thornell; discussion by L. I. Birdsall and R. E. McDonnell.

After luncheon in the rooms of the Chamber of Commerce of Cedar Rapids, the Section assembled at 2:00 p.m. These papers were then read:

Bacterium coli and Bacterium aerogenes in Swimming Pools, by Max Levine; discussion by W. W. Deberard, F. G. Merkel, Dow R. Gwinn and Jack J. Hinman, Jr.

The Load Curve for Construction Equipment (illustrated), by Homer V. Knouse; discussion by Wm. Luscombe, George T. Prince, Thos. Healey, R. E. McDonnell and J. Chris Jensen.

The Present Status of Water Purification in Iowa (illustrated), by Jack J. Hinman, Jr.; discussion by Lewis I. Birdsall, Dow R. Gwinn and H. V. Pedersen.

Dow R. Gwinn then read a short paper entitled, The Attitude of the Water Works Operator Toward the State Health Officer.

In a business session the report of the Nominating Committee was read. The selections of the committee were as follows:

Chairman, Edward Bartow; Vice-Chairman, H. F. Blomquist; directors, R. N. Tracy and Max Levine.

The report was unanimously approved and the secretary was instructed to cast a unanimous ballot for these gentlemen as the officers of the Section for the ensuing year.

Max Levine then invited the Section to hold its ninth annual meeting at Ames, Iowa, extending the invitation on behalf of the City of Ames and of the Iowa State College of Agriculture and Mechanic Arts. The invitation was referred to the incoming executive committee consisting of the newly elected officers.

The session was adjourned until six o'clock.

Immediately after the session, the newly elected officers met and appointed Jack J. Hinman, Jr., Secretary-Treasurer. They also voted to hold the next meeting at Ames, Iowa.

At 6:00 p.m. the Section was tendered an excellent dinner in the rooms of the Chamber of Commerce of Cedar Rapids by the Chamber of Commerce and Cedar Rapids Society of Engineers and Architects.

Mr. Leefers, President of the Cedar Rapids Society of Engineers and Architects, introduced Dr. Harry M. Gage, President of Coe College, Cedar Rapids, Iowa, who acted as toast master. Mr. Louis Roth, Commissioner of Finance, welcomed the Section on behalf of the City of Cedar Rapids. Chairman J. Chris Jensen responded on behalf of the Iowa Section. Charles R. Henderson gave a short historical talk entitled, The American Water Works Association and the Iowa Section.

Mr. Henderson then moved that Chairman Jensen be made an honorary member of the Section at the end of his term as Trustee at Council Bluffs. Carried.

John M. Grimm gave an eloquent address entitled, Some Civic Assets, followed by a paper by Dow R. Gwinn on Publicity of the Right Sort for Water Works Properties.

The John Klepach Construction Company of Cedar Rapids, showed a moving picture of the construction of the new sewer and a half million gallon reservoir at Cedar Rapids, following which the Section adjourned until Friday morning.

On Friday, November 3, in the rooms of the Cedar Rapids Chamber of Commerce, D. R. Gwinn's paper of the evening before was discussed by L. I. Birdsall, R. E. McDonnell, George T. Prince, Charles R. Henderson, Homer V. Knouse, Max Levine, J. Chris Jensen and D. R. Gwinn.

A motion was made to give Dow R. Gwinn a vote of thanks for his interesting and valuable paper. Carried.

The papers scheduled on the program were read as follows:

The Use of Hydrogen Ion Measurements in Connection with the Cedar Rapids Water Supply, by Frederick C. Mortensen; discussion by W. W. DeBerard and L. I. Birdsall.

The Value of Sedimentation in Water Purification at Cedar Rapids, by Clinton O. Bates; discussion by L. I. Birdsall and W. W. DeBerard.

Some Problems of the Cedar Rapids Water Works Plant, by H. F. Blomquist; discussion by R. E. McDonnell.

The Resolution Committee brought in a series of resolutions, for action by the Section, voting thanks to various persons and agencies extending cooperation during the meetings. All these resolutions were passed.

The Committee then introduced the following special resolutions:

WHEREAS it is known that many public and private water supplies in the State of Iowa are unsatisfactory as a result of poor location and poor construction of the wells, and through faulty distribution systems,

AND WHEREAS these unsatisfactory supplies are in such condition, in many cases as a result of the lack of knowledge of the dangers of surface contamination and as a result of the failure of the general public to realize the necessity of securing and maintaining a safe water supply,

AND WHEREAS the general education of the people of the State of Iowa and the proper supervision of water supplies throughout the State are the only practical means of overcoming these difficulties,

AND WHEREAS it is obvious that this supervision should be carried on through the State Board of Health, because of the very nature of its duties now imposed by law,

AND WHEREAS the Department of the State Board of Health which is now charged with the supervision of the Sanitation of the State is entirely inadequate because of the lack of personnel and sufficient appropriation,

Therefore Be It Resolved by the Iowa Section of the American Water Works Association in convention at Cedar Rapids, Iowa, that the Section through its Legislative Committee, bring this state of affairs to the attention of the next General Assembly and request the Assembly to create a Division of Sanitation within the State Board of Health, and to appropriate funds sufficient to permit the maintenance of a sufficient corps of engineers proficient in sanitation to carry on an efficient, state-wide supervision of water supplies, and otherwise to promote the improvement of sanitation throughout the State of Iowa.

This resolution was carried unanimously.

WHEREAS the direction of the water works departments in the majority of cities and towns of the states of the Iowa Section of the American Water Works Association, when not under the city manager, or commission types of government, is by law placed in the hands of the city councils elected by popular vote,

AND WHEREAS the terms of office of the several members of such bodies expire concurrently, resulting in a periodic change of the entire personnel of the directing officials,

AND WHEREAS such changes of personnel reflect in the water departments by constant change and shifting of the policies of operation, resulting in inefficiency which the superintendent or water works manager is unable to remedy,

Therefore Be It Resolved that the Iowa Section of the American Water Works Association in convention at Cedar Rapids, Iowa, go on record as favoring the adoption of the Trustee System of Water Works management, wherein the various members have overlapping terms of office, for the control of the water supplies of the cities and towns of this district, owning and operating their own water works plants, and that a copy of this resolution be placed in the hands of the members of the Legislative Committee for consideration.

Carried.

William Molis read his paper on Tubular Wells, which was to have been read on Wednesday afternoon. Time was not available for discussion.

Following the session of Friday morning the manufacturers representatives gave a complimentary luncheon to the members of the Section in the rooms of the Chamber of Commerce.

At 2:00 p.m. the members of the section were taken in cars furnished by the Chamber of Commerce to visit the following places of interest.

New Reservoir of the Cedar Rapids Water Works.
The Cedar Rapids Pumping Station and Filter Plant.
The Puffed Grains Plant of the Quaker Oats Company.

NORTH CAROLINA SECTION

The second annual meeting of the North Carolina Section was held at Gastonia, N. C., on November 14 to 16. A novel feature of the gathering was the holding of the regular meetings on the lower floor of the new two million gallon water filtration plant of the city. This plant, recently completed, afforded an opportunity for inspection to the many visiting superintendents.

The registration was one hundred and twenty, by far the largest attendance ever at any meeting of water works men in the state. Of those present about 47 were superintendents, filter plant operators, or otherwise actively engaged in water supply operation. The principal consulting engineers of the state, engaged in the design of water supplies and purification plants, were present, and a number of manfacturer's representatives were engaged in describing the interesting exhibits.

In addition to inspecting the details of the new filtration plant under the guidance of the superintendent, C. E. Rhyne, those attending the meetings were taken in cars to the new activated sludge sewage treatment plant, designed by William Piatt of Durham. This plant makes use of a modification of the MacLachlan process of sludge dewatering by use of sulphur dioxide gas generated at the plant. This modification was devised by William Piatt and is working most satisfactorily, the sludge after being treated and pressed, appearing as an inoffensive sludge cake, which is used for fertilizer.

C. W. Grantham, City Manager of Goldsboro, urged the Section to take some steps toward obtaining a State Plumbing Code. The secretary, Thorndike Saville, described briefly the work being done by the sub-committee on plumbing of the United States Department of Commerce and the outline for a model plumbing law which it was soon to issue. It was suggested that a committee of the Section be appointed to consider the question of a State Plumbing Law and report its recommendations to the next annual meeting.

A spirited discussion took place with regard to charges for private fire services. Sherwood Brockwell, Deputy State Insurance Commissioner, presented the insurance side of the case, while City Managers Grantham of Goldsboro and Alexander of Gastonia spoke from the point of view of the municipality.

The chief discussions were brought out in connection with papers by J. O. Craig on Water Rates, by A. McK. Maffitt and J. S. Bennett on Universal Pipe, by M. N. Boyles on Experience with Wood Stave Pipe, and by W. D. Cates On Water Works Superintendents' Responsibility for Fire Fighting. W. D. Cates mentioned that in the recent serious fire in Atlanta, the threads on hydrants had been so badly worn by use of hydrants for street flushing as to interfere seriously with their use for fire service.

An agreeable feature of the meetings was a complimentary banquet given by the city on the second evening following a get-to-gether dinner held on the first evening. Addresses were delivered by Mayor Cherry of Gastonia and by President Ludlow. The water works men present were enthusiastic in their expressions of approval of the work the Section is doing, of the value received from the papers, and of the good time and good fellowship enjoyed. The Hill membership cup occupied an imposing position at the dinner. This cup is given annually to that section of the A. W. W. A. having the greatest per cent increase in membership, and was won by the North Carolina Section last year. The Section was organized in September, 1921, with 23 members, and now has about 40. The membership is continuing to increase, and the Section expects to be able to retain the cup for at least another year.

Papers of particular interest, other than those mentioned above, were, Drilling and Care of Deep Wells by J. C. Godfrey; Design and Use of Centrifugal Pumps by T. C. Heyward; Use of Oxy-acetylene Torch in Water Works Practice by J. C. Michie; Use of Deep Well Water to Secure Alkalinity by J. C. Womble; The Laboratory Control of Filtration by G. D. Norcom; Operation of a Small Filter Plant by R. J. Ward; The Importance of Filter Sand and Gravel in Filtration Plants by A. O. True; Operation of Mechanical Filters with Value of Simple Laboratory Tests by W. M. Turner; The Lexington, N. C., Filtration Plant by W. L. Jones; Operation of Chlorine Control Apparatus by P. J. Dishner; Economical Control of Chemical Dosage in Filtration Plants by R. A. Maddock; The Operation and Care of Centrifugal Pumps by R. M. Alexander and Combustion of Coal in Boiler Furnaces by A. McK. Maffitt.

A noteworthy feature of the meeting, of especial interests to filtration plant operators, was the presentation of the paper by E. J. Theriault of the United States Public Health Service on Use of Hydrogen Ion Determinations. Dr. Theriault gave an interesting

and non-technical discussion on what hydrogen ion determinations mean to the water works operator, and the lines along which studies are being prosecuted to make this determination of greater practical value. Following Dr. Theriault's address, G. F. Cattlett of the State Board of Health and G. D. Norcom of Wilmington described investigations being conducted in this state on hydrogen ion determinations. Whereas Dr. Theriault had found that a pH value of 5.5 gave generally optimum conditions for precipitation of a floc from aluminum sulphate, in this state the pH value for good precipitation ranged from 4.2 at Wilmington to 6.6 at other places, depending upon the local characteristics of the water being treated.

The success of the metings was due largely to the untiring efforts of the enterprising City Manager of Gastonia, W. J. Alexander, who did not spare himself in putting every facility of his office at the disposal of the Section, as well as providing the use of the new filter plant for meetings and arranging for the complimentary dinner given those attending.

The officers elected for the ensuing year are President, E. B. Bain; Vice-President, J. O. Craig and Secretary and Treasurer, Thorndike Saville. The Section voted to hold its next annual meeting at New Bern, in the eastern part of the state.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Keeping Efficient Water Works Records with Card Ledgers. L. R. PLIMPTON. Fire & Water Eng., **72**: 89, July 19, 1922. Discussion of advantages of card ledger in water works office.—*Geo. C. Bunker.*

Institution of Water Engineers; Presidential Address at Annual General Meeting. W. J. E. BINNIE. Water & Water Eng. (London), **24**: 214, June 20, 1922. Following subjects are discussed: necessity of securing reliable information concerning rainfall and run-off on areas from which water supplies will be taken; reservoir storage; compensation water; underground supplies; and parliamentary procedure.—*Geo. C. Bunker.*

Littleton (Middlesex) Reservoir. (Note). Water & Water Eng., **24**: 260, July 20, 1922. Metropolitan Water Board's new open reservoir, one of largest in the world, is expected to be completed in 2 years' time. Storage capacity, 6,500,000,000 gals. Circumference, about 4 miles. About 3-3/4 million cu. yds. of excavation. Reservoir will be fed from the Thames river by open conduits. Outlet leads into two 6 ft. mains which will run to the Kempton Park filters. From the latter the water will be delivered to a new long-distance service reservoir to be constructed at Hampton. A new pump station with a capacity of 300,000,000 gals. per 24 hours will be built at a point adjacent to the River Ash. At Walton there will be another pump station with a maximum capacity of 35,000,000 gals.—*Geo. C. Bunker.*

The Absolute Pressure Gage: Its Construction and Use. V. P. GRIFFIN. Power, **55**: 1011, June 27, 1922. Recommended as more practical in testing condensers and air pumps than a gage of the barometer type. Illus.—*Geo. C. Bunker.*

Cleaning Inspirator Tubes Produced Different Results. H. D. YODER. Power, **55**: 1015, June 27, 1922. Trouble data on injectors.—*Geo. C. Bunker.*

Fire Hazards in Plants Using Pulverized Coal. L. D. TRACY. Power, **55**: 1030, June 27, 1922. Excerpts of address before the Fire Chiefs' Club of Ohio.—*Geo. C. Bunker.*

Why Engines Are Compounded. Power, 56: 17, July 4, 1922. Points out that compounding is in interest of economy and not increased power. Illus.—*Geo. C. Bunker.*

Boiler Plant of the American Sugar Refining Company, Baltimore, Md. Power, 56: 2, July 4, 1922. Refinery represents the latest practice in industrial plant design. Boiler plant contains 5 boilers of 12,060 square feet heating surface each, plus 26 per cent integral economizer surface, fired by forced-draft chain-grate stokers. Fuel is small-sized anthracite "creek coal." Furnace is designed to improve the gas mixture and decrease the carbon loss to the ash-pit. Cooling air for furnace arches is used as preheated excess air in combustion chamber. Illus.—*Geo. C. Bunker.*

Steam Traps: Their Selection, Installation and Upkeep. E. Smiley. Power, 56: 45, July 11, 1922. Gives many pointers on selection, installation and upkeep of traps, one of which is the method of distinguishing the actual leakage of steam from the vapor formed by re-evaporation.—*Geo. C. Bunker.*

Indicator Diagrams of Compound Engines. Power, 56: 55, July 11, 1922. Illus.—*Geo. C. Bunker.*

Oil Engine vs. Steam Power. Chas. E. Lucke. Power, 56: 81, July 18, 1922. The heavy-oil engine has developed rapidly in recent years. This rapidity of advance has hardly been noticed by engineers outside the field. The heavy-oil engine is today a competitor against steam as it never was before. It is going to be more widely competitive in the future. The problem is to define when and where oil engines give cheaper power than steam or vice versa, to select and to determine on what sort of facts a selection should be made. The following features are discussed: efficiency of small oil-engines; comparative fuel costs; saving in labor charges; comparison of total charges. Illus.—*Geo. C. Bunker.*

The Problem of Lubricating Steam-Engine Bearings. W. F. Osborne. Power, 56: 53, July 11, 1922. Generally speaking, the oil should have the lowest viscosity that will form and maintain the lubricating film with a sufficient margin of safety. Unnecessarily high viscosity will increase frictional losses within the bearing and raise the steam consumption. Because of the low speed at which most steam engines operate, formation of a perfect oil film is a difficult matter, unless all conditions are properly adjusted. On this account the circulatory system is of great advantage in securing best results, because it furnishes a large volume of oil to all the bearings. The oil on a steam engine is subjected to contamination due to the admixture of condensed steam carrying emulsified cylinder oil. Emulsified cylinder oil and water have a great tendency to emulsify the rest of the engine oil in the system. High viscosity of cylinder oil also raises viscosity of the engine oil, and the increased viscosity, together with the content of emulsified animal oil, causes the engine oil to deteriorate rapidly. Different oils recommended for different conditions. (This is one of a series of weekly articles started in the issue for

January 3, 1922 in which some phase of lubrication is discussed. More attention should be given to the selection of lubricating oils for use in water works, to the observation of their behavior under different conditions, and to the methods of cleaning used oils. Resident chemists at filter plants will increase their usefulness and broaden their knowledge by taking an interest in the lubrication problems of the pump stations. Superintendents of water works should also interest themselves in the subject for the use of a cheap oil does not necessarily mean that the cost of lubrication will decrease and neither does the selection of an oil of higher price insure the proper oil for the local conditions G. C. B.)—*Geo. C. Bunker.*

On the Use of Chlorine Gas in the Purification of Sewage. J. TILLMAN. Gesund. Ing., **45**: 255–59, 1922. In a series of experiments on 5 liter quantities of sewage, treated with amounts of Cl. gas ranging from 3 to 20 p.p.m., results were obtained showing that by the addition of small amounts of Cl (1) rate of decomposition of sewage can be greatly decreased, (2) acid conc. may be held nearly constant, (3) nitrate decomposition takes place more slowly, (4) the formation of H_2S takes place more slowly, (5) the albuminous compounds are more slowly attacked. It is recommended that in case a relatively large volume of sewage must be discharged into a stream of small volume, a treatment with Cl. be used in order to delay decomposition of the sewage until it can reach a larger body of water, and thus avoid local nuisance.—*Jack J. Hinman, Jr., (M.F.) (Courtesy Chem. Abst.)*

Dr. W. P. Dunbar, Obituary. DR. KAMMANN. Gesund. Ing., **45**: 254–55, 1922. Review of life and achievments of Dr. W. P. Dunbar, Director of the Hygienic Institute at Hamburg for 29 years, who was largely responsible for growth and importance of that organization. Dunbar was well known for his contributions to hygiene and water purification.—*Jack J. Hinman, Jr.* (M.*F.*) (*Courtesy Chem. Abst.*)

Investigation on the Elbe Water at Magdeburg and Hamburg. OTTO WENDEL. Zeit. angew. Chemie, **35**: 219–23, 1922. Compares average monthly sanitary analyses of the Elbe water of 1921, and average for years since 1912. River in 1921 showed little change in salt concentration. Ammonia, nitrous and nitric acids are never more than traces. Concentration of org. compounds is greater in winter, during low water and when ice is present.—*Jack J. Hinman, Jr. (M.F.) (Courtesy Chem. Abst.)*

Der praktische Gas- und Wasserinstallateur. DR. OTTO KALLENBERG. 2nd Edition, 368 pages, Publishers, Ernst Heinrich Moritz (Inh. Franz Mittelbach) Stuttgart, Price (in Germany) paper cover, 45 marks, bound 60 marks. A practical handbook and text. Reviewed in Gas- und Wasser-Fach, 65, 95, (1922).—*Jack J. Hinman, Jr., (M.F.) (Courtesy Chem. Abst.)*

Making 30-inch Flexible Joint Cast-Iron Pipe. WM. G. HAMMERSTROM. Engineering-News Record, **88**: 19, 780, May 11, 1922. Details of manufacture, with illustrations, of 30-inch cast-iron pipe with machined spherical-shaped

bell and spigot. This flexible joint pipe is to be used by City of Norfolk for river crossings.—*A. W. Blohm.*

Report on the Results of the Chemical and Bacteriological Examination of the London Waters for the Twelve Months Ended March 31, 1922. Sir Alexander Houston. Sixteenth Annual Report of the Metropolitan Water Board. Report contains, in detail, the progress throughout the year, in purifying water from the Thames, Lee and New Rivers, the principal sources of London's water supply. The results of the numerous samples analyzed are tabulated, and the merits of, rapid and slow sand filtration, sedimentation, hypochlorite of lime and liquid chlorine, in the purification of water, are discussed.—*A. W. Blohm.*

Prospective Problems from Present Depreciation Methods. E. E. Bankson. Pennsylvania W. W. Assn. 1921 Report. Page 238. Cases decided by Pennsylvania Commission show a range in annual allowance for depreciation of about 33 times as much for West Reading as for Higins. Commission should require a minimum rate of return on the straight line fund to be counted as revenue of the Company rather than to let it lie idle in the rate base upon which we ask the consumers to pay 7 per cent. By the sinking fund method, whether the retirance funds are invested inside or outside the business, they must earn interest for their own aggrandizement in order to provide the full amount at the end of life. This fund is not free capital, and its only source of return is through the rate base. Reduction of rate base due to accrued depreciation is a positive injustice to the owners, unless provision is definitely made for retiring an equivalent amount, but such an act would defeat the very purpose of the replacement fund which is to have the amount of money in hand to replace the plant item retired. Correct application of sinking fund depreciation contemplates a continuance without decrease of the same rate-making-value as fixed today; modified by plant extensions and retirements. But if the rate base must be fixed on depreciated plant value then the retirance must be computed on the remaining life of the plant items. The sinking fund method of depreciation maintains a higher depreciated plant value than under the straight line theory.—*E. Bankson.*

Practical Methods of Financing Extensions. Charles Haydock. Pennsylvania W. W. Ass. 1921 Report. Page 268. The writer believes that a company is warranted in using its depreciation fund to finance extensions. The surplus account is a source of funds for financing extensions when money can be had at a less rate than 7 per cent. It is seldom feasible to dispose of securities in small blocks which are required for extensions. Many companies require the consumers to excavate and backfill the trench, the company furnishing and laying the pipe, or consumer assists materially in financing the extensions, or build the extension with funds advanced by the consumer to be refunded later and taken over when the annual revenues reach a proper sum.—*E. Bankson.*

Value, Cost, Law and Justice in Rate Regulation. JOSEPH A. BECK. Pennsylvania W. W. Assn. 1921 Report. Page 281. The Honorable Charles Evans Hughes pointed out that the decisions of our courts are as close an approach to justice and right as anything of human origin. They begin to feel their way, and they finally take a position which is in accordance with the principles of right and justice after full argument on both sides. The valuation of a public utility for rate-making purposes is a legal question and is to be determined according to the established rules of law. The rule has been established and fixed that the present value of a utility's property for rate making purposes is determined by the market value of the land and reproduction cost of structures less depreciation. As a matter of fact value is not determined by its cost. Value is determined by the equation of supply and demand. Value tends to equal cost in the competitive field but not with reference to plants for supplying water to the public. This formula disregards the original cost. Let me express my belief that this established rule of law is in accord with justice, though prices may come down. The utility will not be hurt if there is a change in the level of prices and a change in the value of the income from the property, if we regard this change in the value of money. *Discussion, by J. N. Chester, page 300:* When prices broke, cast iron pipe went from above eighty to less than forty. Now suppose the Commission had a case before it at eighty dollar prices, and before their decision was handed down prices had dropped to forty, would not the city upon which these rates were imposed have a right to ask for a re-argument. *Discussion, by Mr. Gannett, page 302.* With Mr. Chester we want something more stable than present costs, something that does not fluctuate quite so much; something upon a par with the fixed bond interest rate.—*E. Bankson.*

Utilities under Public Service Commissions. GEORGE S. DAVISON. Pennsylvania W. W. Assn. 1921 Report. Page 310. The first attempt to regulate pulbic utilities was by Massachusetts in 1869. No serious efforts were made generally until 1907. Absence of regulation was a good thing because many companies were thereby promoted, though in such a way that the public mind went wrong on the proper attitude towards public utilities. The initiative for promoting was rewarded by swelling securities, overhead charges, required large incomes, service was curtailed, competition began discriminating practices, managements became overbearing, and after a long period laws were enacted providing fair play. The fairness of rates and quality of service are legal propositions to be determined by the courts, with the Public Service Commission acting as a committee of the same. The removal of the opportunity for duplicating plants cheapens the cost of service. Uniform classification of accounts is one of the important features of the Pennslyvania Law. It requires a long time after entering upon their duties as Commissioners, to learn that the men furnishing public service are just as honest, intelligent and capable as those pursuing other walks of life. The Commissioner often fails to appreciate how little an increase in rates affects the customer's total expenses. Of the cases here cited, public service costs slightly over seven per cent of the income, and the water bill a fraction of one per cent. The daily average of these items is less than what is spent by an average single family for

cigars, sodas, movies, and chewing gum. The revenue allowed (limited study) in Wisconsin for fire protection is 33.11 per cent of the gross revenue, and in Pennsylvania 18.29 per cent. If Commissions will ignore what a million dollars looks like in a valuation, and discover the small burden that the taxpayer must carry to sustain it, it will mean the difference between insolvency and unimpeachable credit for the company in many cases.—*E. Bankson.*

Electric Generation of Chlorine. Clarence W. Marsh. Pennsylvania W. W. Assn. 1921 Report. The electrolytic generation of chlorine at its point of application by the use of electrolytic cell batteries eliminates many objections to the use of chlorine.—*E. Bankson.*

New Water Meter Rates for Detroit. George H. Fenkell. Eng. News-Record, **89**: 449, 1922. Detroit is 99 per cent metered. Proposed rate for a ⅝ inch meter is $2 per year for service charge and $36 for a 4 inch meter. The use charge is 50 cents per 1000 cubic foot for the first 100,000 cubic foot and thereafter 35 cents. A householder with a ⅝ inch meter using 1000 cubic foot or less per quarter will pay $4 per year. The change in rate was made because of increased overhead operating and maintenance charges due to installation of filters to be in operation early in 1923.—*Frank Bachmann.*

The Sacramento Floating Type of Aerator Nozzle. Harry N. Jenks. Eng. News-Record, **89**: 384–6, 1922. A new low-head aerator nozzle with a central floating cone invented for use in the water purification plant at Sacramento, Cal. Advantages claimed: simplicity of design; exceptional trash passing ability; uniformly excellent spray at all discharges; adaptability to different head-discharge requirements, particularly for low heads; hydraulic characters readily modified, chiefly by altering the weight of the central floating cone. It is propsed to aerate the river water to remove tastes and odors by means of nozzle sprays.—*Frank Bachmann.* (*Courtesy Chem. Abst.*)

A New Method of Purifying water. H. W. Clark. Eng. News-Record, **89**: 514, 1922.—*Frank Bachmann.*

Slow Sand Filtration Plant for Hartford, Conn. Caleb Mills Saville. Eng. News-Record, **89**: 380–4, 1922. Water is obtained from two reservoirs having a combined capacity of 10.7 billion gallon. The estimated safe yield from this source is 32 m.g.d. Actual consumption is approximately 13.5 m.g.d. or 81.5 gallons per capita. A slow sand filter plant was put in operation in February having a capacity of 17.5 m.g.d. Reasons for deciding on slow sand instead of rapid sand filters were: no chemical required to obtain a water of satisfactory color; less danger of conditions which are deleterious to service pipes; no intricate mechanism to get out of order. Comparison of cost of the 2 types shows that they are approximately the same in first cost.—*Frank Bachmann* (*Courtesy Chem. Abst.*)

Cement-Lined Cast-iron Pipe at Charleston, S. C. J. E. Gibson. Eng. News-Record, **89**: 387–90, 1922. Tests show that, with Charleston water, tar

coated cast-iron pipe is unsatisfactory, because of tuberculation reducing materially the discharge. From 70 years experience at a number of cities using cement lining, observations indicate no decrease in the discharge after long usage. Charleston is laying some 10 miles of cement lined cast-iron pipe.—*Frank Bachmann.*

Use of Sulphuric Acid with Alum in Water Purification. John R. Baylis. Eng. News-Record, **89**: 351, 1922. The addition of H_2SO_4 to the alum solution reduced the alum required for treating Baltimore water supply. An actual test over a period of 32 hours treating 150.6 m.g.d. required 7.211 tons of alum costing $216.33 and 5 tons of 66° Be H_2SO_4 costing $90. Lime was used to neutralize the increase of CO_2. The total cost of chemicals by this method was $326 compared with $450 if acid had not been used. As 100 m.g.d. is usually treated, a daily saving of about $82 is anticipated.—*Frank Bachmann* (*Courtesy Chem. Abst.*)

Comprehensive Program for Denver Water-Works System. Dabney H. Maury, H. T. Cory, and H. S. Crocker. Eng. News-Record, **89**: 360–1, 1922. Control of South Platte water and use of Marston Lake recommended. Ultimate supply will provide 200 m.g.d. Construction costs are estimated at $6,700,000. In the filter plant tastes and odors are eliminated by aeration. The filter plant will consist of 16-4 m.g.d. units having a filtration rate of 150 m.g.d. per acre per day.—*Frank Bachmann* (*Courtesy Chem. Abst.*)

Laying 30-inch Submerged Pipe for Norfolk Water-Works. Davis A. Decker and John O. Miller. Eng. News-Record, **89**: 393–5, 1922. By means of a curved timber cradle suspended between two barges, flexible-joint cast-iron pipe was laid at three important submerged crossings on the 20-mile supply line from Lake Prince to the distributing system of Norfolk, Va. To get good joints the bells were heated, pipe length lifted to cradle, bells reheated, and joints poured from special pots holding 275 lbs. lead. Methods of laying the pipe are detailed.—*Frank Bachmann.*

Reinforced Concrete for Water Retaining Structures. H. C. Ritchie, Can. Engineer. **43**: 4, July, 1922. General theory of design assumes that steel rods embedded in concrete may be stressed up to 16,000 pounds or even as high as 20,000 pounds per square inch without detriment to the structure. Assumed, further, that the moduli of elasticity of both steel and concrete are constant, so that the modular ratio is constant, and this value is taken at from 10 to 15 for the quantities of concrete used in this class of work. Assumptions indicate that, before the 16,000 pounds per square inch stress on the reinforcement can be reached, the concrete surrounding the steel must have cracked, as the corresponding stress in this concrete taking the higher modular ratio of 15 would be in excess of 1000 pounds per square inch. Allowable stress in reinforcing steel was gradually brought down to about 11,000 to 12,000 pounds per square inch and very satisfactory results obtained. Author's practice in designing water-holding structures primarily considered the stresses on the composite sections of steel and concrete, keeping the unit

tensile stress within the limit which experience has shown will yield watertightness. Where direct tensile stress in the concrete is go be considered, this should not be allowed to exceed 10 per cent of its ultimate compressive resistance at 30 days, which for a 3:1½:1 concrete would give 200 pound per square inch and for 4:2:1 concrete 160 pounds per square inch giving a ratio of working tensile stress to ultimate compressive stress at four months of 1:15. The effective spacing of expansion joints 25 to 30 feet is sufficient to allow in work where watertightness is essential. Provision of such joints serves to relieve the structure of the stresses due to temperature changes. Experiments made in the National Physical Laboratory (England), to ascertain the rates of percolation of water through concrete slabs 4 inches thick, concrete mixtures being 4:2:1 and 2⅝:1⅛:1, showed percolation at first was quite rapid but gradually dropped after nine weeks when it became constant. Suggestion that reduction was due to silting up process by deposit of calcium carbonate was found to be only secondary cause. Mechanical analysis of sand and aggregate, and all voids being properly filled should render concrete practically impermeable. Author produced a 2:1:1 mixture, concrete slabs 2 inches thick which under 96 feet head of water for five days showed no percolation.—*N. J. Howard.*

Copper Sulphate Treatment for Preventing Algae Growths in Lakes and Reservoirs. N. L. Huff. Can. Engineer **43:** 9, August 1922. Application of copper sulphate from a row boat in burlap sack showed that 100 pounds could be dissolved in an hour or 250 to 300 pounds could be dissolved in the same time when using a small motor boat. Temperature of water, organic matter, hardness and carbonic acid content important factors in successful treatment. With proper supervision the use of copper sulphate is absolutely safe; without such supervision it may be disastrous.—*N. J. Howard.*

Securing Water for Condensing Plant at Portobello Power Station. Edinburgh, Scotland. Anon. Can. Engineer. **43:** 11, Sept. 1922. To supply cooling water for condenser 3 vertical shafts have been sunk in the Firth of Forth to a depth of 60 feet and from bottom of these shafts, tunnels 4 feet 9 inches in diameter driven seawards a distance of 1,500 feet. Surface condensers are to be used, each having 5,000 ¾ inch diameter brass tubes approximately 18 feet long. About 840,000 gallons of water per hour will be required for each of the three 10,000 kilowatt turbo-alternator sets.—*N. J. Howard.*

Poirrier Blue C-4-B as Color Indicator. W. Mestrezat. J. pharm. chim. **23:** 489–94, 1921. From Chem. Abst. 16:215, January 20, 1922. Examination showed that poirrier blue C-4-B cannot replace methyl orange in the titration of free alkali in presence of carbonate. The color change is progressive, and the shade "distinctly blue" is not obtained at neutrality.—*R. E. Thompson.*

Methyl Orange as Indicator in Presence of Indigo Carmine. Frank X. Moerk. Am. J. Pharm. **93:** 675–9, 1921. From Chem. Abst. **16:** 215, January 20, 1922. The following solutions, designated as A, B, C, and D (C and D preferentially), gave uniform results when used as indicators in the titration of

sulphuric acid, phosphoric acid, borax, carbonate, hydroxide and phosphate with decinormal solutions:

	METHYL ORANGE	INDIGO CARMINE	WATER
	grams	*grams*	*cc.*
A	1.0	3.6	1000
B	1.333	4.0	1000
C	1.0	2.5	1000
D	1.0	3.0	1000

The color change is from a violet or purplish color with acid to green or yellow with alkali and the addition of 1 drop of decinormal acid of alkali to the titrated solution will produce a distinct change. A neutral blank containing 0.2 cc. of indicator in 100 cc. of water should be used during the titration.—*R. E. Thompson.*

Effect of the Presence of Filter Paper on Permanganate-Oxalate Titrations. Stephen G. Simpson. J. Ind. Eng. Chem. **13**: 1152–4, 1921. From Chem. Abst. **16**: 215–216, January 20, 1922. In titrating oxalates with potassium permanganate in the presence of filter paper satisfactory results can be obtained, except in cases where great accuracy is required, by adding manganese sulphate and titrating slowly or by washing the oxalate off the paper with hot water and adding the paper when the titration is almost complete. The results are unsatisfactory when the paper is present in highly disintegrated form. (Compare Halverson and Schulz, J. Ind. Eng. Chem. **12**: 77–8, 1920. using ignited non-reducing asbestos.—Abstractor.)—*R. E. Thompson.*

Application of the Laws of Chemical Kinetics to Quantitative Analysis. J. Clarens. Bull. soc. chim. **29**: 837-52 (1921). From Chem. Abst. **16**: 216, January 20, 1922. By studying the absorption of oxygen by solutions agitated in the presence of this gas it is evident that the rate of absorption varies from time to time, which indicates different stages in the oxidation and the probable formation of three different substances. The total oxidation was found to be about one third of that resulting from the action of potassium permanganate in a boiling solution.—*R. E. Thompson.*

Removal of Air from Pumps and Suction Lines. H. W. Centr. Zuckerind, **28**: 422–4, 1921. From Chem. Abst., **16**: 644, March 10, 1922. An apparatus for this purpose is described.—*R. E. Thompson.*

Coagulation of Colloids by Electrolytes. H. D. Murray. Chem. News, **123**: 277–9, 1921. From Chem. Abst., **16**: 668, March 10, 1922. Work on the precipitation of colloids by added electrolytes is reviewed and references are given. Six facts seem to have an important bearing on the theory. (1) the specific action of ions of opposite sign, (2) the greater effect of higher valency, (3) the modifying action of ions of the same sign as the colloids, (4) the possible

adsorption of equivalent quantities of ions, (5) a minimum necessary concentration of electrolyte, (6) the possible effect of an ion originally present. If the work of different investigators is to be comparable four conditions are necessary: (1) uniform concentration of colloid, (2) rapid and uniform mixture of colloid with electrolyte, (3) uniform treatment after mixing and (4) uniform size of colloidal particles.—*R. E. Thompson.*

Note on Medalia's Method of Determining Hydrogen-ion Concentration. N. K. Smitt. Bull. Bur. Bio-Technology, No. 4, 105-7, (1921). From Chem. Abst., **16**: 729, March 10, 1922. A short discussion of the method from the viewpoint of the modern theory of indicators. See C. A. 15, 3650—*R. E. Thompson.*

State of the Products of the Emanation of Radium in Water Studied in Relation to the Phenomenon of Adsorption and of Isotopes. H. Lachs and H. Herszfinkel. J. Phys. Radium **2**: 319–28, 1921. From Chem. Abst., **16**: 680, March 10, 1922. Experiments on the filtration of aqueous solutions of the products of Ra Em are described. It is probable that radioactive substances are ionic, since they are displaced by ions. It is not possible to prove that they are not colloidal since in the presence of colloids they also are colloidal.—*R. E. Thompson.*

A Band Absorption Spectrum of Water for Wave Lengths of Several Decimeters. R. Weichmann. Physik. Z-, **22**: 535–44, 1921. From Chem. Abst., **16**: 684, March 10, 1922. The refraction and absorption of electric waves by water are dealt with. It is considered probable that water possesses a regular band spectrum for wave lengths of 27 to 65 cm. and longer.—*R. E.Thompson.*

The Fluid Extract of Clover, a Substitute for Bouillon. Yoshiwo Fukutomi. Med. News (Jap) No. 1067, 1921; Jap. Med. World, **1**: 4, 22, 1921. From Chem. Abst., **16**: 732, March 10, 1922. A 1 per cent clover was boiled in 1 liter of water for one-half hour. This extract was used as a culture medium without further treatment. Various species grew better on this medium than control cultures in Liebig's bouillon.—*R. E. Thompson.*

Preparation of Chloroplatinic Acid by means of Hydrogen Peroxide. Paul Rudnick. J. Am. Chem. Soc. **43**: 2575-7, 1921: see C. A. **11**: 1101. From Chem. Abst. **16**: 791, March 10, 1922. Residues of potassium chloroplatinate are dissolved, filtered and recrystallized. The ethyl alcohol is removed from alcohol filtrates and these and all aqueous filtrates are reduced with zinc and hydrochloric acid. Organic compounds other than sodium formate are avoided. The crude platinum black, which has been allowed to become dry after reduction, is thoroughly washed by decantation, suspended in concentrated hydrochloric acid, concentrated hydrogen peroxide free from preservatives added and hydrochloric acid gas bubbled through. The dissolved platinum is precipitated by potassium chloride. The reagent is prepared by reducing a weighed amount of potassium chloroplatinate with alkaline sodium formate, dissolving the washed platinum black as above and making the solu-

tion up to the proper volume as calculated from the weight of potassium chloroplatinate taken.—*R. E. Thompson.*

Typhoid Fever and Prejudice Against Chlorination of Drinking Water. R. G. Perkins. U. S. Public Health Bull.; Munic. County Eng. **51**: 154, 1921. From Chem. Abst. **16**: 777, March 10, 1922. The reduced dosage of chlorine which has been used since 1912, owing to complaints of taste, has proved ineffective in at least 2 years as shown by the typhoid increase.—*R. E. Thompson.*

Preparation of Sodium Hydroxide free from Carbon Dioxide. J. Cornog. J. Amer. Chem. Soc. **43**: 2573–4, 1921. From Chem. Abst. **16**: 694, March 10, 1922. To boiled and cooled water ethyl ether is added to make a 3–4 cm. layer and sodium added in pieces not exceeding 1 cm. in diameter. They fall no further than the ether layer and the slowly formed sodium hydroxide passes readily to the water layer. There is no danger of explosion or fire if the ether layer is kept 3–4 times the diameter of the largest pieces of sodium added. Most of the ether can be pipetted off and the remainder removed by boiling.—*R. E. Thompson.*

Thermite-Welded Pipe Joints. R. L. Browne. Am. Soc. Refrig. Eng. J. **7**: 452–9, 1921. From Chem. Abst. **16**: 705, March 10, 1922. The process of welding is described. In bursting and tensile-strength tests upon these pipes in no case did the rupture occur at the weld. Vibration tests, of 225 vibrations per minute each of 2 in. amplitude, upon 12-foot specimens of welded and coupled pipes showed no injury to the welded pipes after 1,566,340 vibrations, while the coupled pipes broke at the root of the threads after 6160 and 3430 vibrations respectively. The method is not adaptible to sheet-metal work.—*R. E. Thompson.*

The Purification of Potable Waters by Chlorine. H. Pecker. Bull. sci. pharmacol. **28**: 459–66, 1921. From Chem. Abst. **16**: 771, March 10, 1922. The chlorine index, the determination of which is essential to the control of chlorination, is the amount chlorine, in mgms., fixed during a period of 30 minutes by 1 liter of water to which 5 mgms. of chlorine have been added. Sodium hypochlorite is the source of added chlorine.—*R. E. Thompson.*

Chlorination of Potable Water. Anon. Ministry of Health, Circ. 241, Sept. 15, 1921; Lancet 1921, 671; Public Health Eng. Abst. Dec. 17, 1921. From Chem. Abst. **16**: 771, March 10, 1922. Sterilization with chlorine is described under the general headings: removal of the taste of chlorine; adaption of method to quantity; and difficulties and safeguards.—*R. E. Thompson.*

Boiler Feed Water Purification. S. B. Applebaum. Chem. Met. Eng. **25**: 992, 1921; see C. A. 15, 3355. From Chem. Abst. **16**: 772, March 10, 1922. A reply to a criticim by Taylor (C. A. 15, 4034). Zeolite softeners, if properly constructed and operated, will reduce the hardness of a water to zero. Sodium salts influence the capacity of a softener but do not prevent the production

of "zero water." The increase in the mineral content of the water during the softening process is less than 5 per cent.—*R. E. Thompson.*

Annual Report of the Division of Water, Toledo 1921. 30 pp. July, 1922. *Report of the Assistant Commissioner,* G. N. SCHOONMAKER. A substantial increase in pumping efficiency was recorded, approximately 10 per cent more water being pumped per pound of coal used than in the previous year. Compounding of velocity meters resulted in considerably increased revenue. Revised specifications require that all meters 4-inches or over in size must be compound meters, those below being of the disc type. The cleaning of a 12-inch pipeline effected a reduction in loss of head from 34.5 to 2.15 feet in 5000 feet and increased the capacity of the line 300 per cent. Complete general, financial, administration and pumping statistics are given. *Report of Construction Engineer.* I. G. FOWLER. The construction work carried out during the year is outlined. 22 new filters were completed, making a total of 56 million gallon filter units. Distribution statistics are given. *Report of Chemist in Charge.* R. W. FURMAN. The average daily consumption of water was in excess of 26 million gallons. Difficulty in obtaining complete reactions with iron sulphate and hydrated lime treatment under low temperature conditions resulted in an increase of sand incrustation up to 39 per cent, and a reduction in filter efficiency. Subsequent alum treatment decreased this incrustation to 30 per cent and rendered the remaining portion semi-porous. A reduction in the amount of lime used in the iron sulphate treatment also was found effective in reducing the incrustants. Purification records for the year are included.—*R. E. Thompson.*